Thesis Submission for
Doctor of Philosophy in Physics

Field Containment of Plasma Positron Annihilation Using Tesla Coil to Generate and Contain.

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questions others have not yet asked and/or answered, and then to use that knowledge and add it to humanity's collective.

Brief Abstract

This research investigates a method and apparatus for controlling plasma positron annihilation using a Tesla coil. The research investigation employs high-frequency electromagnetic fields generated by a Tesla coil to manipulate plasma positron dynamics and interactions with controlled annihilation.

By exploring the interaction between plasma and positrons while employing the electromagnetic field properties of the Tesla coil, this research aims to provide new insights into controlled annihilation processes. The method provides precise confinement and control of positrons, facilitating applications in advanced propulsion systems for space travel and potential directed energy weapons.

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Chapter 1. Introduction

Background

Positrons (e^+), the antimatter counterparts of electrons, undergo annihilation upon interaction with plasma – an ionized gas consisting of free electrons and ions - electrons (e^-), resulting in the release of photon energy (gamma rays) and/or the release of quarks and the boson particle, gluon. Each fundamental particle responds to electromagnetic (EM) fields and as such can be influenced by EM fields. Understanding these interactions are critical for understanding and controlling the plasma positron annihilation process.

Significance

Controlling positron annihilation in plasma could lead to breakthroughs in controlled nuclear fusion and antimatter research. Utilizing Tesla coils, known for their high-voltage and high-frequency electromagnetic fields, presents a novel approach to manipulating and controlling these interactions.

Objective

To determine if Tesla fields generated by a Tesla coil can be used to direct and control plasma positron annihilation.

Scope

This research focuses on applying the current theoretical and acquired knowledge of plasma, positrons, and Tesla coils, to control and harness matter-antimatter annihilation.

Outline

The thesis is structured into chapters detailing the literature review, theoretical framework, methodology, experimental results, discussion, and conclusion.

The Bohr model provides a useful but limited understanding of sub-atomic particles, with the introduction of limitations required of such a simplistic model. The <u>first</u> fundamental error is the perspective that <u>electrons</u> are solid objects. The universe is composed of quantumly defined energies. At lower quantum energies the material building blocks of the universe give the appearance of objectively measurable solid objects, while at higher energies these same building blocks have appear as measurable frequencies with wave (λ) phenomena. The conservation of this mass-energy continuum was defined Albert Einstein's special relativity theory

$$E = mc^2$$

where:

E = the energy measured in joules,
m = the mass in kilograms, and
c is the speed of light measured in meters per second

Thus, all mass and energy in the universe is conserved and as demonstrated in the dual-slit experiment, behaves as both solid (lowest energy) and waves (highest energy) at any given point in time. It is our interaction with the universe that lowers the energy to that which is observed and measured.

The highest energy is frequently referred to in photon units as is defined by the Planck-Einstein relationship:

$$E = hf$$

where:

E = the photon energy measured in joules,
h [Planck's constant] = 6.625 x 10^{-34} joules per second or 6.625 x 10^{-27} ergs per second,
f = the frequency in cycles per second; viz. hertz (Hz).

When these energy systems are in motion, their energy-momentum relationship is defined by the Lorentz factor, i.e., the changes in the physical properties of an object changes when the object is moving through space, including mass, length and time; as described by:

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} = \sqrt{\frac{c^2}{c^2-v^2}} = \frac{c}{\sqrt{c^2-v^2}} = \frac{1}{\sqrt{1-\beta^2}} = \frac{\Delta t}{\Delta \tau}$$

where:

γ = the Lorentz factor,
v = the relative velocity in meters per second between inertial reference frames,
c = the speed of light measured in meters per second,
β = the ratio of "v" to "c",
Δ = delta or difference in,
t = the coordinate time of observer, and
τ = the proper time of observer (i.e., the measured time interval from observer's time frame).

Consequently, when considering energy-momentum relationships, as must be done when electromagnetic fields are applied using a Tesla coil as proposed in this research, for both the production of plasma and containment of plasma positron annihilation, Einstein's special relativity for energy mass conversion becomes:

$$E=\gamma mc^2$$

where:

E = the energy measured in joules,
γ = the Lorentz factor,
m = the mass in kilograms, and
c = the speed of light measured in meters per second

A <u>second</u> fundamental error found with the Bohr model is the representation that the universe is composed entirely of <u>matter</u>. While Paul Dirac first postulated the existence of anti-matter in 1928 when he tried to reconcile Schrödinger's linear partial differential equation, which predicts future behavior of dynamic (energy) wave systems, with Einstein's mass-energy special relativity equation [$E=mc^2$], it was not until 1932 that evidence of positrons in cosmic radiation was discovered.

While prior physicists seemed perplexed by the possibility of antimatter, Dirac asked a fundamental question. Is it possible to have two solutions to a problem; one positive and one negative. The simplicity of the question was phrased with the equation, what is "x"?

$$X^2 = 4$$

The now famous answer is X can be both 2 or -2.

In 1932 Carl David Anderson discovered antimatter positrons in a cloud chamber at the California Institute of Technology (aka Caltech). The subsequent observation that

matter and antimatter annihilate each other with the calculated release of 2-511 MeV photon's has since raised questions regarding the potential use for this energy source.

The energy produced from plasma positron annihilation, while theoretically substantial on a per-event basis, presents practical challenges when scaling up to useful quantities. It is this question of controlled plasma positron annihilation control and regulation that this research focuses on.

POTENTIAL APPLICATIONS OF THIS RESEARCH

1. Scientific Research and Experimental Physics

Particle Physics Experiments: The controlled annihilation of plasma and positrons can be used in experiments to study fundamental particle interactions, antimatter properties, and high-energy physics phenomena.

Positron Emission Tomography (PET): Although the first positron emission tomography (PET) scanners were built by Edward Hoffman, Michael M. Ter-Pogossian and Michael E. Phelps last year (1973) at Washington University with DOE and NIH monies, future applications and advancements include radioactive isotopes generation and control including but not limited to Tesla coil-generated plasma for medical imaging.

2. Compact Energy Sources

Micro Power Generators: Small-scale applications could benefit from plasma positron annihilation if efficiency and containment issues can be resolved. Devices requiring precise and small amounts of power, such as nanoscale sensors or microelectromechanical systems (MEMS), could be potential beneficiaries.

3. Radiation Sources

Gamma Radiation Production: The gamma photons produced during plasma positron annihilation could be harnessed for industrial radiography, sterilization processes, or other applications requiring controlled radiation sources.

FEASIBILITY AND PRACTICAL LIMITATIONS

1. Scale of Energy Production

Low Power Output: The energy produced from plasma positron annihilation, while theoretically substantial on a per-event basis, presents practical challenges when scaling up to useful quantities. Using the example calculation where 10^{12} plasma positron annihilates per second would produce approximately 1.637 joules per second (or 1.637 watts). This 1.637 watts is relatively low power and would be insufficient for most practical applications that require continuous and significant energy supply, e.g., such as powering household appliances, electric vehicles, or industrial machinery.

Scaling Challenges: Increasing the number of plasma and positrons generated and annihilated per second to produce kilowatt or megawatt levels of power presents significant technical and engineering challenges.

2. Efficiency and Containment

Positron Production: Generating positrons efficiently requires high-energy interactions typically achieved in particle accelerators, which are more complex and energy-intensive than Tesla coils.

Containment and Control: Capturing and confining positrons long enough to ensure their annihilation with plasma electrons is technologically demanding. Magnetic or electrostatic confinement methods need to be highly advanced and efficient.

3. Safety Considerations

Radiation Hazards: The gamma radiation produced from positron annihilation is highly penetrative and poses significant safety risks. Shielding and protective measures would be crucial in any practical application to protect humans and sensitive equipment from radiation exposure.

4. Energy Conversion and Infrastructure

Conversion Efficiency: Converting the gamma photons produced from annihilation into usable electrical or thermal energy efficiently is another challenge. Current technology for such conversion is not highly efficient. Given the absence of effect of EM upon gamma radiation as shown in Figure 1, demonstrates the need to use Tesla coil technology to both increase plasma positron annihilation as well as direct the

annihilation energy source by directing the plasma positron annihilations toward a port for release of the gamma energy.

<u>Infrastructure Requirements</u>: Developing the necessary infrastructure to handle and utilize plasma positron annihilation energy will require significant investment in research, development, and safety measures.

INTRODUCTION CONCLUSION

While the energy from plasma positron annihilation is substantial on a per-event basis, the current practical limitations significantly restrict its application. Generating, containing, and efficiently utilizing plasma positron annihilation energy currently remains more of a scientific curiosity than a feasible power source with today's technology. Advancements in particle physics, materials science, and engineering may eventually overcome these challenges, potentially opening new avenues for energy generation and utilization in niche applications including space travel and potential weapons systems.

Chapter 2. Initial Literature Review and Contributions to the Field.

A complete list of referenced material is presented in chapter 8. This chapter will focus on specific literature as it relates to important contributors in the fields of plasma research, positrons, and Tesla coils.

UNDERSTANDING PLASMA POSITRON PHYSICS

Review of positron discovery, properties and early research from the 1930s to 1973, includes a brief discussion of Dirac's theory of antimatter and experimental techniques for positron production and detection.

Positron plasma annihilation refers to the process where positrons (the antimatter counterparts of electrons; e^+) in a plasma interact with electrons (e^-), resulting in mutual annihilation as shown in Figure 2. This annihilation process theoretically either results in (a) the conversion of the mass of the positron-electron pair into 2-511 KeV gamma photon energy units, or (b) the release of a lesser quantity of gamma photon energy with conservation of matter resulting in the generation of both a matter quark (q) and anti-matter quark ($\overline{q}$) with release of gluon (g) particle. We will now focus on the first of these two as the principle method for producing maximum energy production from the pair annihilation.

For purposes of clarity, for the remainder of this thesis the term plasma refers to the electron component of plasma, as this is the direct component which the positron interacts with.

Here is the step-by-step description of plasma (electron) positron plasma annihilation:

1. Positron and Electron Interaction: In a plasma containing positrons, these antiparticles can collide with electrons. Since positrons have the same mass as electrons but opposite charge, they are attracted to electrons.

2. Annihilation Event: When a positron encounters an electron, they can annihilate each other. This annihilation process converts the mass of both particles into energy according to Einstein's mass-energy equivalence principle, $E=mc^2$.

3. Gamma (Photon) Production: The typical result of an electron-positron annihilation is the production of two photons, each with an energy of 511 keV (kilo-electron volts), which corresponds to the rest mass energies of the electron and positron. The two photons are emitted in approximately opposite (~ 180 degree) directions to conserve momentum.

4. Plasma Characteristics: Positron plasmas can be created and confined in laboratory settings using magnetic fields, in addition to other techniques. This research focuses on plasma generated through Tesla magnetic fields. These are of interest in the fields of astrophysics and controlled nuclear fusion given the unique properties of plasmas composed of equal amounts of matter and antimatter.

5. Applications and Studies: Investigating positron plasma annihilation can improve our understanding of fundamental particle interactions, allow for the development of enhanced materials (through positron annihilation spectroscopy), and augment our exploration of theoretical aspects of antimatter. In astrophysics, positron annihilation is observed in phenomena such as gamma-ray bursts and the environments around black holes and pulsars.

Overall, positron plasma annihilation is a critical process in both fundamental physics research and practical applications, providing insights into the behavior of antimatter and the fundamental symmetries of the universe.

DIRAC'S THEORY OF ANTIMATTER:

Paul Dirac's theory on antimatter emerged from his efforts to reconcile quantum mechanics and special relativity, leading to the formulation of the Dirac equation in 1928. The Dirac equation describes the behavior of relativistic electrons and predicts the existence of particles with the same mass as electrons but opposite charge. These particles are now known as positrons, the antimatter counterparts of electrons.

Key Points of Dirac's Theory:

1. Dirac Equation: The equation incorporates both quantum mechanics and special relativity:

$$(i\gamma^{\mu}\partial_{\mu} - m)\psi = 0$$

where:

i is the imaginary unit, ensuring that the wave function (ψ) remains consistent with the principles of quantum mechanics,
∂_{μ} denotes the partial derivative with respect to spacetime coordinates,
m is the mass, and
ψ is the wave function, and
γ^{μ} is the gamma matrices, where μ ranges from 0 to 3 satisfying the Clifford algebra

$$\{\gamma^{\mu}, \gamma^{v}\} = 2\eta^{\mu v} I$$

where:

$\{,\}$ denotes the anticommutator,
I is the 4 x 4 identity matrix, and

$\eta^{\mu v}$ is the Minkowski metric tensor, whose components are ((x, y, z special) and t(time) components),

$$\eta^{\mu v} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \end{pmatrix}$$
$$\eta^{\mu v} = \begin{pmatrix} 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}$$

In special relativity, the Minkowski metric is used to calculate the spacetime interval (s^2) between two events. This interval is given by:

$$s^2 = \eta_{\mu v} x^{\mu} x^{v} = (ct)^2 - x^2 - y^2 - z^2$$

where:

x = x-coordinate in space,
y = y-coordinate in space,
z = z-coordinate in space,
t = time coordinate,

$x^{\mu} x^{v}$ are the four-vectors representing the coordinates of the events, and
c is the speed of light.

The interval remains invariant under Lorentz transformations including rotations and boosts, that preserve the structure of spacetime.

The Minkowski metric tensor provides the foundation for measuring distances and intervals in four-dimensional spacetime, ensuring the consistency of theory of special relativity. It defines the invariant spacetime interval and is crucial for describing the geometry of flat spacetime in relativistic physics.

In summary, the Dirac equation integrates these components to describe relativistic spin – ½ particles, capturing their behavior under the influence of both quantum mechanics and special relativity. Dirac's equation successfully predicted the existence of antimatter, including the positron, and provided a theoretical foundation for quantum field theory and the Standard Model of particle physics.

Dirac's theory on antimatter and subsequent experimental advancements in positron production and detection have profoundly impacted physics, leading to significant developments in both fundamental research and practical applications such as medical imaging.

2. Negative Energy Solutions: The Dirac equation admits solutions with both positive and negative energy. To avoid physical inconsistencies, Dirac proposed that all negative energy states are filled in a "Dirac sea," which is a theoretical model where these states are occupied by electrons. A "hole" in this sea would appear as a positively charged particle.

3. Prediction of Positrons: The "holes" in the Dirac sea were later identified as positrons. Dirac initially interpreted these holes as protons but soon realized they had to be new particles with the same mass as electrons and opposite charge.

4. Experimental Confirmation: Carl Anderson experimentally discovered positrons in 1932, providing empirical validation of Dirac's prediction. He observed positrons in cosmic rays using a cloud chamber, confirming their existence and verifying Dirac's theory.

EXPERIMENTAL TECHNIQUES FOR POSITRON PRODUCTION AND DETECTION

1. Production of Positrons

Beta Decay: Certain isotopes undergo beta-plus decay (positron emission), where a proton in the nucleus is converted into a neutron, a positron, and a neutrino. [See figure 1.] For example, ^{18}F decays to ^{18}O by emitting a positron (e^+) [aka beta particle β^+] and a neutrino (v).

Pair Production: High-energy photons interacting with a nucleus can produce an electron-positron pair. This occurs when the photon has energy greater than 1.022 MeV (twice the rest mass energy of the electron and positron).

Particle Accelerators: High-energy collisions using particle accelerators are expected to be able to produce positrons in the not distant future. The soon to be operational Super Proton Synchrotron (SPS) is expected to be able to produce positrons and advance particle physics research using the world's first proton antiproton super collider.

2. Detection of Positrons

Cloud Chambers: Early experiments used cloud chambers to detect the tracks of charged particles. Positrons leave tracks that curve in the opposite direction to electrons in a magnetic field, due to their positive charge.

Bubble Chambers: Bubble chambers are similar to cloud chambers. These chambers use a superheated liquid coupled with a sudden decrease in chamber pressure to produce a "superheated metaphase" liquid, allowing ionized particles, including positrons, to form a track around which the liquid vaporizes, forming microscopic "bubbles". The density of the bubbles around the ion track is proportionate to the energy loss of the ionized particles.

Scintillation Counters: These devices detect positrons by measuring the light produced when positrons interact with scintillating material. This is commonly employed in nuclear imaging.

Solid-State Detectors: Semiconductor detectors, such as silicon detectors, measure the ionization produced by positrons.

Coincidence Counting: In positron annihilation studies, the simultaneous detection of the two 511 keV gamma rays emitted during electron-positron annihilation provides a signature of positron presence.

3. Positron Emission Tomography (PET)

PET scanners use positron-emitting isotopes to image metabolic processes in the body. The emitted positrons annihilate with electrons, producing gamma rays that are detected and reconstructed to form images.

EXPERIMENTAL TECHNIQUES FOR PLASMA PHYSICS INCLUDING PRODUCTION AND DETECTION

Irving Langmuir was a pioneering American physicist and chemist whose work significantly contributed to developments in plasma physics. Langmuir's research in this field laid the groundwork for understanding various properties and behaviors of plasmas, which are often referred to as the fourth state of matter.

Key Contributions of Irving Langmuir to Plasma Physics.

1. Discovery of Plasmas

Plasma Concept: In the 1920s, while studying electrical discharges in gases, Langmuir coined the term "plasma" to describe the ionized gas composed of ions, electrons, and neutral particles. He observed that these ionized gases exhibited collective behavior distinct from those of ordinary gases.

Definition: Langmuir described plasma as a quasi-neutral gas of charged and neutral particles exhibiting collective behavior.

2. Langmuir Probe

Development: Langmuir developed an instrument called the Langmuir probe to measure the electron temperature, electron density, and electric potential in plasmas.

Function: The probe consists of a conducting wire inserted into the plasma. By measuring the current-voltage characteristics of the probe, important plasma parameters can be determined.

Impact: The Langmuir probe remains a fundamental diagnostic tool in plasma physics research and applications.

3. Plasma Oscillations

Discovery: Langmuir, along with his colleague Lewi Tonks, discovered plasma oscillations, also known as Langmuir waves. These are high-frequency oscillations of the electron density in a plasma.

Theory: They demonstrated that electrons in a plasma can collectively oscillate around their equilibrium positions, leading to wave-like phenomena. This work was fundamental in understanding wave propagation in plasmas.

4. Debye Shielding (aka Electrostatic Sheath)

Concept: Langmuir's research contributed to the understanding of Debye shielding, a process by which a plasma - due to the electrons having an order of magnitude greater temperature, and as such are faster than the surrounding ions - charge the surface with a relatively negative charge compared with the surrounding plasma, screens out electric fields over a characteristic length scale known as the Debye length. The Debye length is:

$$\lambda_D = \sqrt{\frac{\frac{\varepsilon_0 k_B}{q_e^2}}{\frac{n_e}{T_e} + \sum_j \frac{z_j^2 n_j}{T_j}}}$$

where:

λ_D *is Debye length,*
ε_0 is the permittivity (absolute dielectric of classical vacuum; capacitance of the vacuum) of free space [approximated as 8.85 x 10-12 Farads per meter (F/m)],
k_B is the Boltzmann constant [1.380649 x 10-23 joules per kelvin (J/K)],
q_e is the charge of an electron (1.602 176 634 x 10^{-19} coulombs),
T_e is the temperature of the electrons,
n_e is the density of electrons,
n_j is the thermodynamic average in the associated electric potential field,
z_j is zeptojoules (10^{-21}), and
T_j is the temperature of ions/species.

Significance: Debye shielding explains why electrostatic potentials in plasmas are shielded beyond a certain distance, affecting how plasmas interact with their environment and with external electric fields.

5. Applications and Legacy

Plasma Devices: Langmuir's work has had lasting implications for the development of various plasma devices and technologies, including fluorescent lights, plasma TVs, and fusion reactors.

Interdisciplinary Impact: His contributions extend beyond plasma physics to fields

such as surface chemistry, where he also made significant strides, earning the Nobel Prize in Chemistry in 1932 for his work on surface chemistry and adsorption.

Key Contributions of Francis F. Chen's to Plasma Physics.

Francis F. Chen is a prominent physicist renowned for his extensive work in plasma physics. He has made significant contributions to both the theoretical understanding and practical applications of plasmas, and his textbooks are widely used in the education of new generations of plasma physicists.

1. Chen's Experimental and Theoretical Work Textbook and Educational Contributions entitled "Introduction to Plasma Physics and Controlled Fusion".

Summary: Chen's textbook, due to be published later this year (1974), is a comprehensive introduction to the field. It covers fundamental plasma physics concepts, including plasma confinement, waves, instabilities, and various applications.

2. Specific Contributions

Plasma Diagnostics: Chen has contributed to the development of various plasma diagnostic techniques, including Langmuir probes, which are crucial for measuring plasma parameters such as density, temperature, and potential.

Waves in Plasmas: Chen's work includes extensive research on plasma waves and instabilities. He has studied wave propagate in plasmas and how they can be used for diagnostics and heating.

Plasma Confinement and Controlled Fusion: Chen has researched methods for confining plasma in magnetic fields, which is essential for controlled fusion as well as this (my) research. His work has contributed to the understanding of how to maintain stable plasma conditions necessary for sustained nuclear fusion reactions.

3. Chen's Plasma Applications

Magnetohydrodynamics (MHD): Chen has worked on the principles of MHD, which describes the dynamics of electrically conducting fluids like plasmas. His research has implications for both astrophysical plasmas and engineering applications.

Industrial Applications: Chen's work has implications for plasma applications in industries.

Francis F. Chen's contributions have had a lasting impact on plasma physics, both in terms of theoretical advancements and practical applications. His work has helped to deepen our understanding of plasma behavior and has provided essential tools and techniques for research and industry. His textbooks continue to be vital resources for students and researchers in the field.

ANNIHILATION MECHANISMS

Positron annihilation mechanisms vary depending on the medium in which the positron encounters electrons. The nature of the medium—whether it is a vacuum, gas, liquid, or solid—affects the way positrons annihilate with electrons, as well as the resulting products and their characteristics. The following information provides an overview of annihilation mechanisms in different media.

1. Vacuum

The first practical application of vacuum systems began with the work of the English physicist, John Ambrose Fleming, PhD. It has been said that this was the beginning of the modern electronics era, when Fleming developed the first thermionic diode in 1904 followed by his 1905 work on oscillating waves. This work evolved into rectifier tubes and eventually lead to Irving Langmuir's work.

In a vacuum, positrons and electrons can annihilate without interference from surrounding atoms or molecules. The primary annihilation mechanism is:

<u>Direct Annihilation</u>: A positron directly encounters an electron, and they annihilate each other, typically resulting in the production of two gamma photons with energy of 511 keV each, emitted in opposite directions to conserve momentum as shown in figure 2.

2. Gas

In a gaseous medium, positrons can undergo several processes before annihilation:

<u>Direct Annihilation</u>: Similar to a vacuum, positrons can directly annihilate with free electrons, producing two 511 keV gamma photons.

<u>Positronium Formation</u>: Positrons can form a bound state with electrons called positronium. Positronium exists in two forms:

Para-Positronium (p-Ps): This is the singlet state (total spin 0) with a lifetime of about 125 picoseconds in a vacuum. It annihilates primarily into two gamma photons.

Ortho-Positronium (o-Ps): This is the triplet state (total spin 1) with a longer lifetime of about 142 nanoseconds in a vacuum. It predominantly annihilates into three gamma photons, each with energy less than 511 keV.

Quenching: In dense gases, collisions with gas molecules can quench positronium, leading to shorter lifetimes and potentially altering the annihilation process.

3. Liquid

In liquids, the behavior of positrons and positronium is influenced by the denser environment.

Positronium Formation and Annihilation: Positronium can still form, but its lifetime is usually shorter due to interactions with the liquid molecules. The annihilation modes (two or three photons) depend on the spin state of positronium.

Solvent Effects: The type of liquid solvent affects the annihilation characteristics. For example, polar solvents might affect the positronium formation rate and its annihilation process.

Bubble Formation: In some liquids, positrons can create small bubbles, isolating them from the liquid and altering the annihilation characteristics.

4. Solid

In solid materials, positron annihilation processes are more complex due to interactions with the lattice structure and electron density.

Trapping and Annihilation: Positrons can get trapped in defects, vacancies, or voids in the solid lattice. These trapped positrons can annihilate with surrounding electrons.

Positronium Formation: In certain solids, positrons can form positronium, which can then annihilate within the solid. The positronium might have a shorter lifetime compared to gases due to interaction with the solid matrix.

Defect Analysis: The characteristics of positron annihilation (lifetime and gamma

photon energy distribution) are used in techniques like positron annihilation spectroscopy (PAS) to study defects and electron density in solids.

ANNIHILATION PRODUCTS AND THEIR DETECTION

The following approaches are currently available for detection of annihilation products; i.e., emitted gamma photons.

<u>Gamma Photons</u>: The most common and detectable product of positron-electron annihilation are gamma photons. In the case of direct annihilation or para-positronium annihilation, or plasma positron annihilation, two 511 keV gamma photons are emitted. Ortho-positronium annihilation results in three gamma photons with lower energies as discussed.

<u>Detection Techniques</u>: Various techniques are used to detect and analyze the gamma photons from annihilation events.

> <u>Gamma-ray Spectroscopy</u>: Measures the energy and intensity of gamma photons.
>
> <u>Positron Emission Tomography (PET)</u>: Uses the annihilation gamma photons to create images of metabolic processes in medical diagnostics.

The medium significantly influences the positron annihilation mechanisms, affecting the formation of positronium, the lifetime of the annihilation states, and the resulting gamma photon emissions. Understanding these processes in different media is crucial for applications in material science, medical imaging, and fundamental physics research.

For this research, we will be focusing on the measurement of plasma positron annihilation in a vacuum chamber with "pinch" effect produced by Tesla coil.

TESLA COILS

It is important to consider in brief, a review of some of the historical developments of Tesla coils, Nikola Tesla's pioneering work and subsequent advancements. We will review some the application of Tesla coils in generating high-frequency electromagnetic fields and the potential implications for plasma physics.

Tesla coils are resonant transformers that generate high-voltage, high-frequency alternating currents. They have been used for various applications, including the generation of high-frequency electromagnetic fields and their potential uses in plasma physics.

Historic Development of Tesla Coils.

1. Invention by Nikola Tesla (1891)

Concept: Tesla invented the Tesla coil to explore high-voltage, high-frequency electricity. His goal was to develop wireless transmission of electrical power.

Design: A basic Tesla coil consists of two inductors (primary and secondary coils) and two capacitors. The primary coil and capacitor form a resonant circuit that, when powered, induces a high voltage in the secondary coil through resonance. The design and further claims made by Nikola Tesla's patent 1,119,732 was granted by the United States Patent Office on 1 December 1914.

2. Early Demonstrations and Experiments

Wireless Transmission: Tesla demonstrated wireless lighting and transmission of power using his coils. He envisioned a global system for wireless transmission of energy.

High-Frequency Research: Tesla coils allowed Tesla to conduct experiments with high-frequency alternating currents, leading to advancements in radio technology and the understanding of electromagnetic waves.

3. Developments in the 20th Century

Radio Technology: Early radio transmitters used principles similar to Tesla coils to generate and transmit radio waves.

Medical Applications: In the early 20th century, Tesla coils were used in medical devices, such as diathermy machines, which used high-frequency currents for therapeutic heating.

Applications of Tesla Coils in Generating High-Frequency Emission Fields

1. High-Frequency Electromagnetic Fields:

Generation: Tesla coils generate high-frequency electromagnetic fields through resonant inductive coupling. These fields can ionize gases, create plasma, and produce a range of electromagnetic phenomena.

Wireless Power Transfer: Tesla's vision of wireless power transfer continues to be explored with the potential for modern advancement and applications.

2. Lighting and Displays:

Gas Discharge Lamps: High-frequency fields from Tesla coils can ionize gases in discharge lamps, creating light without the need for electrodes.

Entertainment and Education: Tesla coils are used in demonstrations and educational settings to illustrate principles of high-voltage electricity and electromagnetic fields. They are also popular in artistic displays and performances.

Tesla Coil Potential for Plasma Physics

1. Plasma Generation:

Ionization of Gases: Tesla coils can ionize gases, creating plasma. The high-frequency, high-voltage emissions can strip electrons from gas atoms, resulting in a conductive plasma state.

Cold Plasma: Tesla coils can generate cold plasma, which has applications in sterilization, surface treatment, and medical therapies.

2. Plasma Research:

Diagnostics: Tesla coils are used in plasma diagnostics to study the properties of plasmas. The high-frequency fields can probe plasma behaviors and interactions.

Fusion Research: While Tesla coils themselves are not used directly in fusion reactors, the principles of high-frequency electromagnetic fields are relevant in heating and confining plasmas in fusion research.

3. Material Processing:

<u>Surface Treatment</u>: Plasma generated by Tesla coils can modify the surface properties of materials, such as enhancing adhesion, cleaning surfaces, and creating hydrophobic or hydrophilic properties.

<u>Thin Film Deposition</u>: Plasma-enhanced chemical vapor deposition (PECVD) techniques use plasma to deposit thin films on substrates, a process relevant in semiconductor manufacturing.

SUMMARY OF LITERATURE REVIEW AND CONTRIBUTIONS

Consideration of the above theories and previous work demonstrates the potential to harness plasma positron annihilation energies using electromagnetic field control using Tesla coils. This material provides the basic foundational information and knowledge base needed to measure these annihilations, as well as lay the foundation for the applied use of this energy, through the focused release of the resulting annihilation energy in both the fields of propulsion systems as applied for interplanetary travel and in the potential development of focused (pulsed) weapons systems.

Chapter 3. Integration of Concepts

In the prior chapters we reviewed some of the fundamental concepts leading up to the development of Tesla coils, the recognition of the existence of antimatter with an emphasis on positrons, and the fourth state of matter (plasma), with a recognition that the critical particle of interest in plasma for purposes of this research is the electron (e^-). The theoretical considerations and acquired knowledge provide the framework for this experimental work, focusing on the utilization of enhancing electromagnetic (EM) field strengths using a Tesla coil within a contained vacuum space, to reduce interference with the plasma (e^-) positron (e^+) annihilation process and energy release.

To describe the control of positron annihilation in a plasma using a Tesla coil, we need to discuss the equations governing positron dynamics in an electromagnetic field as well as the interaction rates for positron-electron annihilation. Below are the key concepts and equations required to understand the plasma positron annihilation process within a Tesla coil.

TESLA COIL

A Tesla coil is an electrical resonant transformer circuit invented by Nikola Tesla circa 1891. The primarily use of a Tesla coil is to produce high-voltage, low-current, high-frequency alternating-current electricity. The coil itself consists of two main parts: a primary coil and a secondary coil, each with its own capacitor.

Breaking Down the Components

1. Primary Coil: The primary coil is connected to a power source, typically an AC supply. This creates an oscillating magnetic field around the coil.

2. Secondary Coil: The secondary coil is wound around the primary coil. It has many more turns of wire and is tuned to resonate at the same frequency as the primary coil. This resonance amplifies the voltage.

3. Capacitor: A capacitor is connected in parallel with the primary coil. It stores electrical energy and helps create the resonant circuit.

4. Spark Gap: A spark gap is placed between the primary coil and the capacitor. It consists of two electrodes with a small gap between them. When the voltage across the gap reaches a critical point, it ionizes the air and allows current to flow, discharging the capacitor rapidly.

5. Resonance: The rapid discharge of the capacitor creates a burst of high-frequency oscillating current in the primary coil. This current induces a very high voltage in the secondary coil due to resonance.

6. High Voltage: The voltage in the secondary coil can reach hundreds of thousands to millions of volts. This high voltage creates corona discharges and eventually leads to the formation of electrical arcs at the top terminal (toroid) of the coil, producing spectacular electrical displays known as streamers.

Plasma generation in a Tesla coil occurs when the high voltage at the top terminal ionizes the surrounding air, creating a glowing, ionized gas known as plasma. The intense electric field at the top of the coil strips electrons from air molecules, creating positively charged ions and free electrons. These free electrons collide with other air molecules, causing them to ionize as well. This cascade effect leads to the formation of a plasma column extending from the top terminal of the coil.

In the instance of the vacuum utilized in this study, the electric discharge from the toroid interacts directly with the positron source without interference from other molecules in the air.

AUGMENTATION OF TESLA FIELDS - PINCH

The "continued Tesla pinch" refers to a sustained application of a high magnetic field using the Tesla coil to compress and confine plasma. This concept is referred to as "Z-pinch" or "Bennett pinch" where the electric current is increasing applied through the Tesla coil, increasing the Tesla magnetic field strength, increasing the electron generation within this magnetic field, essentially pinching (constricting) the plasma into a smaller, more confined area, and increasing the interaction of this Tesla generated plasma with the positron source, thereby increasing the plasma (electron) positron annihilation.

When considering plasma positron annihilation in the context of a continued Tesla pinch, several effects are notable:

1. Increased Annihilation Rate: The primary effect of the Tesla pinch is the compression and heating of the plasma. By confining the plasma to a smaller volume, the density of both positrons and electrons increases. This higher density results in more frequent collisions between positrons and electrons, thereby increasing the rate of positron-electron annihilation.

2. Enhanced Plasma Temperature: The compression from the pinch effect increases the kinetic energy of particles within the plasma, raising its temperature. A higher temperature can lead to more energetic interactions, potentially influencing the spectrum of radiation (photons) produced by the annihilation events.

3. Magnetic Field Effects on Particle Trajectories: The strong magnetic fields in a Tesla pinch can alter the trajectories of charged particles (electrons and positrons). This confinement can lead to anisotropies in the plasma and affect the spatial distribution of annihilation events. The magnetic field can also influence the polarization of the emitted radiation from the annihilation processes.

4. Radiation Emission Characteristics: Positron-electron annihilation typically produces gamma photons. The characteristics of the emitted radiation, including its intensity and spectrum, can be affected by the plasma conditions. The high density and temperature conditions induced by the Tesla pinch can shift the radiation towards higher energies and possibly affect the distribution and directionality of the emitted photons.

5. Stability and Instabilities: Sustaining a Tesla pinch requires careful management of plasma instabilities. These instabilities, if not controlled, can lead to turbulent plasma behavior, which might either enhance or inhibit positron annihilation depending on the nature and scale of the turbulence.

6. Fusion and Secondary Reactions: In some cases, the conditions created by a Tesla pinch might be sufficient to induce nuclear fusion if deuterium or tritium ions are present in the plasma. This fusion process can generate additional high-energy particles, which could subsequently interact with positrons and influence annihilation dynamics.

In summary, the continued application of a Tesla pinch to plasma can significantly enhance positron annihilation by increasing the plasma density and temperature, thereby increasing collision rates between positrons and electrons. It also influences the characteristics of the emitted radiation and requires careful control of plasma stability to maintain the desired effects.

TESLA COIL IN A VACUUM - MATERIALS AND EQUIPMENT

A Tesla coil operates by generating high-voltage, low-current, high-frequency alternating current (AC) electricity. In a vacuum, the behavior of a Tesla coil would be significantly different compared to its operation in air. Here's how a Tesla coil should generate electrons in a vacuum.

1. <u>High Voltage Generation</u>: The primary function of a Tesla coil is to generate extremely high voltages. Through electromagnetic induction, the secondary coil of the Tesla coil steps up the voltage from the primary coil to very high levels, often reaching hundreds of thousands to millions of volts. This high voltage is crucial for creating plasma.

The high voltage generated by a Tesla coil can lead to field emission, where electrons are emitted from the surface of the metal components due to the strong electric field. This phenomenon is more pronounced in a vacuum because there are no gas molecules to ionize and carry away the energy.

2. <u>Electric Field Intensity</u>: At the top terminal (toroid) of the Tesla coil, where the voltage is the highest, the electric field intensity becomes extremely strong. This intense electric field strips electrons from molecules present in the chamber, creating positively charged ions and free electrons.

In a vacuum, once electrons are emitted from the electrode, they can be accelerated by the electric field created by the Tesla coil. The lack of air resistance means that these electrons can achieve very high speeds.

3. <u>Ionization</u>: As the electric field ionizes the surrounding molecules, generating ions (positively charged) and free electrons (negatively charged) in the process through collisions between the free electrons and other molecules. The collisions impart enough energy to the molecules to ionize them, creating a cascade effect.

At very high voltages, even a vacuum can break down, leading to a phenomenon known as vacuum breakdown. This could result in a sudden surge of electrons being emitted and accelerated.

4. <u>Plasma Formation</u>: The ionized gas that forms as a result of this process is called plasma. Plasma is often referred to as the fourth state of matter, as it consists of ions and electrons that are not bound together, unlike in solids, liquids, or gases. In the

context of a Tesla coil, the plasma forms a luminous discharge around the top (toroid) terminal, creating the characteristic glowing effect.

If there is a small amount of residual gas within the vacuum, the high voltage from the Tesla coil could ionize this gas, forming a plasma. The plasma would consist of free electrons and positively charged ions, which could conduct electricity and create a visible discharge, similar to a glow discharge or a spark.

In a vacuum, a Tesla coil can generate electrons primarily through field emission and potentially create high-energy electron beams, and Röntgen radiation (aka. X-rays) with emission frequencies between 10^{16} and 10^{20} hertz (Hz; cycles per second). The behavior is influenced by the high electric fields and the lack of air molecules, which allows for more efficient acceleration of electrons and different modes of electrical discharge compared to operation in a gaseous environment.

5. <u>Glowing Discharge</u>: The plasma generated by the Tesla coil emits light due to the movement of charged particles within it. This glowing discharge can take on various colors, depending on the gases present in the surrounding air not adequately evacuated by the vacuum and any additional substances introduced into the environment.

6. <u>Control and Manipulation</u>: While Tesla coils are capable of generating plasma, the process is somewhat uncontrolled in a traditional setup. Efforts to control this include gas composition surrounding the coil, modifying the coil's design to influence the shape and behavior of the plasma, and using additional equipment such as magnetic fields to shape and confine the plasma. In this work, increased Tesla field strengths are produced by increasing electric current strength to produce a "pinch" effect to augment control and annihilation production.

If the electrons accelerated by the Tesla coil strike a metal target within the vacuum, they can generate Röntgen radiation through the process of bremsstrahlung radiation. This occurs because the high-energy electrons decelerate rapidly upon hitting the target material, releasing energy in the form of "X-rays".

TESLA COIL POSITRON GENERATION

While Tesla coils are known for their ability to generate high voltages and create spectacular electrical displays, they are not typically used to generate positrons directly. Positrons (e^+) are the antimatter counterparts of electrons (e^-), with the same mass but opposite charge. Generating positrons requires processes that involve high-

energy particle interactions, such as those found in particle accelerators or nuclear reactions.

However, Tesla coils can indirectly contribute to positron generation in certain experimental setups including:

1. Particle Acceleration: Tesla coils can be used as part of experimental setups for particle acceleration. While they are not as powerful as dedicated particle accelerators, they can produce high-voltage, high-frequency electrical fields. In some cases, these fields can accelerate charged particles, including electrons, to relativistic speeds. When these high-energy electrons collide with a target material, they can generate positrons through processes such as pair production.

2. Pair Production: Pair production is a process where a high-energy photon interacts with a nucleus, producing an electron-positron pair. While Tesla coils do not produce photons directly, they can contribute to the creation of high-energy photons indirectly. For example, if a Tesla coil is used in conjunction with other equipment that generates X-rays or gamma rays, these high-energy photons can interact with materials to produce electron-positron pairs.

3. Plasma Physics Research: Tesla coils are also used in plasma physics research, where they create plasma by ionizing gases. While the primary goal of such experiments is not positron generation, the high-energy environment and interactions within the plasma may lead to the creation of positrons as a byproduct of various particle interactions.

LIMITATIONS TO THE USE OF TESLA COILS FOR POSITRON GENERATION

There are several limitations to using Tesla coils for the generation of positrons:

1. Energy: Tesla coils typically produce high-voltage, high-frequency electrical fields, but they are not as powerful as dedicated particle accelerators. The energies achieved with Tesla coils may not be sufficient to accelerate electrons to the levels required for efficient pair production and positron generation.

2. Efficiency: Even if Tesla coils could accelerate electrons to high energies, the efficiency of pair production—the process by which high-energy photons produce electron-positron pairs—appears to be too low to be practical. Many high-energy photons may interact with the target material without producing pairs, reducing the overall efficiency of positron generation.

3. Control: Tesla coils are relatively simple devices compared to dedicated particle accelerators. Controlling the parameters, such as the voltage, frequency, and target material, to optimize positron generation may be challenging. Without precise control, the efficiency and yield of positron production would appear to be limited.

4. Background Radiation: In experimental setups involving high-energy interactions, background radiation from various sources can interfere with the detection and analysis of positrons. Tesla coils can produce electromagnetic interference (EMI) and induce unwanted electrical signals in detection equipment, making it difficult to distinguish positrons from other particles or noise. In other words, the signal-to-noise ratio would be insufficient to be practical.

5. Safety: Operating Tesla coils at high voltages and frequencies poses safety risks to researchers and equipment. High-voltage discharges can cause electrical shocks, and the production of high-energy photons can pose radiation hazards if proper safety measures are not in place.

6. Cost and Complexity: Building and operating experimental setups involving Tesla coils for positron generation may require significant resources, including specialized equipment, materials, and expertise. The cost and complexity of such setups may limit their accessibility to research institutions with adequate facilities and funding.

In summary, while Tesla coils are not typically used as direct sources of positrons, they can indirectly contribute to positron generation in certain experimental setups involving particle acceleration, pair production, or plasma physics research. However, dedicated particle accelerators and other high-energy facilities are more commonly used for positron generation due to their higher energy capabilities and better control over particle interactions. This research will focus on using 22-Na as its primary positron source.

THE FUNDAMENTAL MATHEMATICAL COMPONENTS

To describe the control of positron annihilation in a plasma using a Tesla coil, we need to understand the basic equations governing positron dynamics in an electromagnetic field and the interaction rates for plasma (electron) – positron annihilation. Below are the eight fundamental key equations.

1. Positron Dynamics in Electromagnetic Fields

The Lorentz force equation describes the force experienced by a charged particle in an electromagnetic field. For positrons, which are positively charged antimatter counterparts of electrons, the equation remains the same as for electrons.

When the Lorentz force is perpendicular to the magnetic field and particle movement, Lorentz force is given by:

$$F = q(E + v \cdot B)$$

where:

F is the Lorentz force experienced by the particle,
q (normally represented as "e" for the charge of an electron) is the charge of the particle (in this case, the charge of the positron) in coulomb,
E is the electric field vector,
v is the velocity vector of the particle in meters per second, and
B is the magnetic field vector in Tesla.

When Lorentz force is not perpendicular, it is derived by:

$$F = qvB\sin\theta$$

Where θ refers to the angle between the velocity of the particle and the magnetic field.

Specifically, these various components are:

1. Electric Field (E): The electric field exerts a force on charged particles. Positrons, being positively charged, experience a force in the direction of the electric field lines if the field is positive, and opposite to the direction of the electric field lines if the field is negative.

2. Magnetic Field (B): When a positron moves through a magnetic field, it experiences a force perpendicular to both its velocity and the magnetic field lines. This force is responsible for the circular motion observed in charged particles moving in a magnetic field, as described by Fleming's right-hand rule.

3. Velocity (v): The velocity of the positron affects the magnitude and direction of the force it experiences. If the positron moves parallel or anti-parallel to the

magnetic field lines, it experiences no force due to the magnetic field. However, if it moves perpendicular to the magnetic field lines, it experiences the maximum force.

4. Charge (q): The charge of the positron determines the strength of the force it experiences in the presence of electric and magnetic fields. Positrons have the same charge magnitude as electrons but positive instead of negative, so they are influenced in the opposite direction by electric fields.

<u>Fleming's Right Hand Rule</u>

The electromagnetism rule for generators and the relationship between field (force), current and motion for generators are described by Fleming's right-hand rule; while Fleming's left-hand rule applies to electric motors. In the instance of the Right-hand rule:

> Imagine a positron moving in a magnetic field (B) with a velocity (v) perpendicular to the field lines. Using the right-hand rule, you can visualize the force (F) acting on the positron.
>
> If you extend your thumb in the direction of the velocity vector (v) and your index finger in the direction of the magnetic field vector (B), then your middle finger will point in the direction of the force (F) experienced by the positron.

This force causes the positron to move in a circular path around the magnetic field lines. The Lorentz force equation quantifies this force, accounting for both the electric and magnetic components, which allows us to predict and understand the motion of positrons in electromagnetic fields.

Positrons, being positively charged, will experience a force in the opposite direction of electrons in the same electric and magnetic fields. This force can cause the positron to accelerate or change direction depending upon the relative strengths and orientations of the electric and magnetic fields.

The Tesla coil generates high-frequency electromagnetic fields that interact with the positrons, influencing their trajectories. This control is crucial for confining the positrons in a desired region within the plasma/chamber.

By combining these factors, the Lorentz force equation accurately describes the motion of positrons in electromagnetic fields, accounting for both electric and magnetic interactions. This equation is fundamental in understanding the behavior of

charged particles in various physical phenomena, including particle accelerators, magnetic confinement in fusion reactors and with Tesla Fields as well as the behavior of cosmic rays in space.

2. Electric and Magnetic Fields of a Tesla Coil

The Tesla coil generates oscillating electric and magnetic fields.

The time-dependent electric field E(t) and magnetic field B(t) can be represented as:

$$E(t) = E_0 \sin(\omega t)$$

$$B(t) = B_0 \cos(\omega t)$$

where:

E_o (electric field amplitude) is the maximum strength of the electric field,
B_o (magnetic field amplitude) is the maximum strength of the magnetic field,
t is time, and
ω is the angular frequency of the oscillations.

These oscillating fields can be tuned to manipulate the positron trajectories and their interactions with electrons (plasma) thereby affecting the plasma positron annihilation process.

3. Boltzmann Equation

The Boltzmann equation describes the distribution function (the dependence between a random variable and its probabilities) of positrons $\mathfrak{f}_p$ (r, v, t) evolves according to the following equation:

$$\frac{\partial \mathfrak{f}}{\partial t} + \left[v \cdot \nabla_r \mathfrak{f}\right] + \left[\frac{F}{m} \cdot \nabla_v \mathfrak{f}\right] = \left(\frac{\partial \mathfrak{f}}{\partial t}\right)_{\text{coll}}$$

where:

$\mathfrak{f}$ (r, v, t) is the distribution function; represents the probability density function of finding a particle at position "r", with velocity "v" at time "t",

e.g. f (r, v, t)d^3rd^3v gives the number of particles in the phase space volume element d^3rd^3v,

$\frac{\partial f}{\partial t}$ is the time derivation of the distribution function; i.e., the rate of change of the distribution function over time due to external influences,

v is the velocity vector of the particle,

$\nabla_r f$ is the spatial gradient of the distribution function,

$v \cdot \nabla_r f$ is the "convective term; i.e., the change in the distribution function due to the motion of particles through space,

F is the force acting on particles (any external force acting on the particles; e.g. gravitational, electric, magnetic),

m is the mas of an individual particle in the system,

$\frac{F}{m}$ is the acceleration experienced by the particle due to the force "F",

$\nabla_v f$ is the gradient of the distribution function with respect to velocity,

$\frac{F}{m} \cdot \nabla_v f$ is the acceleration term, accounting for changes in distribution function due to particle acceleration, and

$\left(\frac{\partial f}{\partial t}\right)_{\text{coll}}$ is the collision term representing the rate of change of the distribution function due to collisions between particles; in contrast to "collision integral" which accounts for the effects of particle interactions on the distribution function.

Further terminology meaning:

1. <u>Distribution Function (f)</u>: Encapsulates the entire statistical state of a system in phase space, providing a comprehensive description of how particles are distributed in terms of position and velocity.

2. <u>Convective Term ($v \cdot \nabla_r f$)</u>: Describes how the distribution function changes as particles move through space, reflecting the transport of particles within the system.

3. Acceleration Term $\left(\frac{F}{m} \cdot \nabla_v f\right)$: Indicates how the distribution function changes due to forces acting on the particles, which can subsequently alter their velocities.

4. Collision Term $\left(\frac{\partial f}{\partial t}\right)_{\text{coll}}$: This captures the effects of particle interactions, which can significantly influence the distribution function; e.g., the scattering and annihilation of plasma positron interactions.

The Boltzmann equation helps model the dynamics of plasma positron interactions, including formation and annihilation events; with the collision term particularly important in describing and accounting for plasma (electron) positron annihilation.

4. Rate Equations

Rate equations describe the time evolution of the number of densities of particles involved in a reaction or interaction. In the context of plasma positron annihilations, the key rate equations govern the densities of positrons, plasma (electrons), and positronium, in addition to the rates of annihilation and positronium formation and decay.

The time evolution of equations of interest includes the rate of change in positron density as shown:

$$\frac{dn_p}{dt} = -R_{ann} - R_{Ps}$$

the rate of change of positronium density as shown:

$$\frac{dn_{Ps}}{dt} = R_{Ps} - \frac{n_{Ps}}{\tau_{Ps}}$$

the rate of plasma positron annihilation:

$$R_{ann} = n_p n_e \langle \sigma_{ann} \upsilon \rangle$$

and the positronium formation rate:

$$R_{Ps} = n_p n_e \langle \sigma_{Ps} \upsilon \rangle$$

where:

d is delta (difference) or change in,

n_p (positron density) is the number density of positrons in the plasma; i.e., the number of positrons per unit volume,

n_e (electron density) is the number density of electrons in the plasma; i.e., the number of electrons per unit volume,

n_{Ps} (positronium density) is the number density of positronium atoms in the plasma; i.e., the number of positronium atoms per unit volume,

σ_{ann} (annihilation cross-section) is the measure of the probability that a positron and a plasma (electron) particle will annihilate each other. This is dependent upon their relative velocities.

σ_{Ps} (positronium formation cross-section) is a measure of the probability that a positron and an electron will form positronium upon encountering each other,

$\sigma_{ann}\upsilon$ (thermally averaged annihilation rate coefficient) is the average value of the product of the annihilation cross-section and the relative velocity, averaged over the velocity distribution of the particles,

$\sigma_{Ps}\upsilon$ (thermally averaged positronium formation rate coefficient) is the average value of the product of the positronium formation cross-section and the relative velocity, average over the velocity distribution of the particles,

τ_{Ps} (positronium lifetime) is the average lifetime of positronium before it decays.

> Para-positronium (p-Ps; spins of positron and electron are oppositely directed; t-1/2 averages 125 nanoseconds (ns)) has a shorter lifetime compared to ortho-positronium (o-Ps; spins of positron and electron are similarly directed; t-1/2 averages 142 ns).
>
> Annihilation decay of p-Ps yields two 511 KeV photons. o-Ps annihilation decay yields three photons – each with less than 511 KeV.

Further terminology meaning:

1. Positronium: The short-lived hydrogen-like atom composed of an electron and positron (in contrast to an electron and proton) arising from the positron capture by the electron, as the positron losses velocity in the process of traveling through matter.

2. Annihilation Rate (R_{ann}): Indicates how rapidly positrons are annihilating with electrons. A higher electron or positron density leads to a higher annihilation rate.

3. Positronium Formation Rate (R_{Ps}): Indicates how rapidly positronium is being formed. Like the annihilation rate, it is proportional to the densities of positrons and electrons.

4. Lifetime of Positronium (τ_{Ps}): Determines the stability of positronium in the plasma. The longer the lifetime, the longer positronium can exist before decaying.

5. Rate of Change of Densities: These differential equations describe how the densities of positrons and positronium evolve over time. They reflect the balance between formation and annihilation processes.

Rate equations describe the time evolution of the number densities of particles involved in a reaction or interaction. In the context of positron plasma (electron) annihilations, the key rate equations govern the densities of positrons, electrons, and positronium, as well as the rates of annihilation and positronium formation and decay.

5. Positron-Electron Annihilation Rate

The annihilation rate of positrons with electrons in a plasma can be expressed as:

$$R = \langle \sigma \upsilon \rangle \eta_e \eta_p$$

where:

R is the annihilation rate per unit volume per unit time,
$\langle \sigma \upsilon \rangle$ is the thermally averaged product of the annihilation cross-section (σ) and the

relative velocity (υ) of the electrons and positrons,
η_e is the number density of electrons,
η_p is the number density of positrons.

This equation ultimately quantifies the rate of annihilation energy release from plasma positron interaction, which could then be harnessed for energy production and use in either propulsion systems used in space travel, or as a potentially destructive focused weapon system(s).

6. Annihilation Cross-Section

The cross-section for positron-electron (plasma) annihilation, particularly at low energies, is derived by:

$$\sigma(v) = \pi r_e^2 \left(\frac{c}{v}\right)$$

where:

$\sigma(v)$ is the effective cross-sectional area for annihilation,
r_e is the classical electron radius equal to 2.817 x 10^{-15} meters,
c is the speed of light in a vacuum (299,792,458 meters per second) – frequently rounded to 3 x 10^8 meters/second,
v is the relative velocity between the annihilation positron and plasma particle (electron).

This describes how the probability of annihilation is dependent upon the relative velocity of the positron and plasma electron particles. This is crucial for both understanding and controlling the annihilation process.

7. Plasma Confinement

The magnetic confinement within a plasma can be described using the pressure balance equation:

$$\frac{B^2}{2\mu_0} = nk_BT$$

where:

B is the magnetic field strength,

μ_0 is the permeability of free space,
n is the plasma density,
k_B is Boltzmann's constant,
T is the plasma temperature.

This equation ensures that the magnetic pressure generated by the Tesla coil's magnetic field is sufficient to confine the plasma.

8. Plasma Frequency

The plasma frequency for positrons (and similarly for electrons) in the plasma is:

$$\omega_\rho = \sqrt{\frac{n_p e^2}{\epsilon_0 m_p}}$$

where:

ω_ρ is the natural plasma frequency oscillations within the plasma,
η_p is the number density of positrons,
e is elementary charge,
ϵ_0 is the permittivity of free space, i.e., the physical constant that reflects the ability of electrical fields to pass through a vacuum, defined as 8.854 187 8128(13) x 10^{-12} farad (capacitance) per meter (F/m); approximated as 8.854 x 10^{-12} F/m – with a relative standard uncertainty of 1.5 x 10^{-10} F/m, and
m_p is the mass of the positron, approximately 9.11 x 10^{-31} kilograms (kg).

Plasma frequency is critical for understanding how the plasma will respond to externally applied electromagnetic fields used in this research.

SUMMARY

Collectively these equations describe the interaction of positrons within an electromagnetic field generated by a Tesla coil and the subsequent annihilation dynamics within the plasma (electron) field so generated. The spectral analysis of the emitted photons provides annihilation information including the temperature and velocity distribution of the plasma. By adjusting the parameters of the Tesla coil, including frequency and amplitude, one can theoretically potentially control the confinement and annihilation of positrons within the plasma.

ETHICAL CONSIDERATIONS

The development of such plasma positron annihilation technologies must be managed responsibly to prevent their misuse and to ensure they are used to provide a benefit for humanity, particularly considering the destructive potential of antimatter weapons.

By working through these equations, and conducting this research guided by these equations and ethical principles, the purpose of this research is to gain a deeper understanding of how we may theorical control and apply plasma (electron) positron annihilation using Tesla coils to space travel and energy production, while understanding the potential use for weapons development, recognizing the need for ethical considerations and regulations.

Chapter 4. Methods for Plasma Positron Annihilation Containment by Tesla Coil

The present experiment involving positron plasma (electron) annihilation contained by a Tesla coil integrates elements of plasma physics, particle physics, and advanced electromagnetism using a Tesla coil inside a vacuum chamber.

To generate positron plasma annihilation measurements in the presence of a magnetic field, we need to consider the effects of the magnetic field on the plasma properties, such as particle confinement, density, and temperature. For simplicity, we will focus on a scenario where we can measure the annihilation rate in a controlled laboratory environment employing varying magnetic field strengths using a Tesla coil.

EXPERIMENTAL PARAMETER LIMITS

1. Magnetic Field Strengths (B): 0 T, 1 T, 2 T, 3 T, 4 T, 5 T.
2. Electron Density (η_e): 10^{19} m^{-3} (constant).
3. Positron Density (η_p): 10^{19} m^{-3} (constant).
4. Plasma Temperature (T): Adjusted for magnetic confinement effects, assume:
   0 T: 10 eV
   1 T: 20 eV
   2 T: 30 eV
   3 T: 40 eV
   4 T: 50 eV
   5 T: 60 eV

5. Classical Electron Radius (r_e): 2.817×10^{-15} m.
6. Electron Mass (m): 9.109×10^{-31} kg.
7. Boltzmann Constant (k_B): 1.381×10^{-23} J/K.
8. Temperature Conversion (eV to K): 1 eV = 1.602×10^{-19} J.

MATHEMATICAL CALCULATIONS BASED UPON EXPERIMENTAL PARAMETER LIMITS

1. Convert Plasma Temperature to Kelvin:

$$T(K) = T(eV) \times \frac{1.602x10^{-19}}{k_B}$$

2. Calculate Thermal Velocity (υ_{th}):

$$\upsilon_{th} \sqrt{\frac{8k_B T}{\pi m}}$$

3. Calculate Annihilation Rate (R):

$$R = (\pi r_e^2)\ (\sqrt{\frac{8k_B T}{\pi m}})(\eta_e \eta_p)$$

ANNIHILATION CALCULATIONS BASED UPON EXPERIMENTAL PARAMETER LIMITS

<u>0 Tesla</u>:

Plasma Temperature (T) = 10 eV = 116,045 K

Thermal Velocity = $\upsilon_{th} = \sqrt{\frac{(8) x\ (1.381 \text{ x } 10^{-23})\ (116{,}045)}{(\pi)(9.109 x 10^{-31})}} \approx 1.32\ x\ 10^6 m/s$

Annihilation Rate = R ≈ $(\pi)(2.817x10^{-15})^2$ x $(1.32\ x\ 10^6 m/s)(10^{19})(10^{19}) \approx 1.47 \text{ x } 10^{26}\ m^{-3}\ s^{-1}$

<u>1 Tesla</u>:

Plasma Temperature (T) = 20 eV = 232,090 K

Thermal Velocity = $\upsilon_{th} = \sqrt{\frac{(8) x\ (1.381 \text{ x } 10^{-23})\ (232{,}090)}{(\pi)(9.109 x 10^{-31})}} \approx 1.87\ x\ 10^6 m/s$

Annihilation Rate = R ≈ $(\pi)(2.817x10^{-15})^2$ x $(1.87\ x\ 10^6 m/s)(10^{19})(10^{19}) \approx 2.08 \text{ x } 10^{26}\ m^{-3}\ s^{-1}$

<u>2 Tesla</u>:

Plasma Temperature (T) = 30 eV = 348,135 K

Thermal Velocity = $\upsilon_{th} = \sqrt{\frac{(8)x\ (1.381 \text{ x } 10^{-23})\ (348{,}135)}{(\pi)(9.109x10^{-31})}} \approx 2.29\ x\ 10^6 m/s$

Annihilation Rate = R ≈ $(\pi)(2.817x10^{-15})^2$ x $(2.29\ x\ 10^6 m/s)(10^{19})(10^{19}) \approx 2.55$ x 10^{26} m^{-3} s^{-1}

<u>3 Tesla</u>:

Plasma Temperature (T) = 40 eV = 464,180 K

Thermal Velocity = $\upsilon_{th} = \sqrt{\frac{(8)x\ (1.381 \text{ x } 10^{-23})\ (464{,}180)}{(\pi)(9.109x10^{-31})}} \approx 2.65\ x\ 10^6 m/s$

Annihilation Rate = R ≈ $(\pi)(2.817x10^{-15})^2$ x $(2.65\ x\ 10^6 m/s)(10^{19})(10^{19}) \approx 2.95$ x 10^{26} m^{-3} s^{-1}

<u>4 Tesla</u>:

Plasma Temperature (T) = 50 eV = 580,225 K

Thermal Velocity = $\upsilon_{th} = \sqrt{\frac{(8)x\ (1.381 \text{ x } 10^{-23})\ (580{,}225)}{(\pi)(9.109x10^{-31})}} \approx 2.97\ x\ 10^6 m/s$

Annihilation Rate = R ≈ $(\pi)(2.817x10^{-15})^2$ x $(2.97\ x\ 10^6 m/s)(10^{19})(10^{19}) \approx 3.31$ x 10^{26} m^{-3} s^{-1}

<u>5 Tesla</u>:

Plasma Temperature (T) = 60 eV = 696,270 K

Thermal Velocity = $\upsilon_{th} = \sqrt{\frac{(8)x\ (1.381 \text{ x } 10^{-23})\ (696{,}270)}{(\pi)(9.109x10^{-31})}} \approx 3.26\ x\ 10^6 m/s$

Annihilation Rate = R ≈ $(\pi)(2.817x10^{-15})^2$ x $(3.26\ x\ 10^6 m/s)(10^{19})(10^{19}) \approx 3.63$ x 10^{26} m^{-3} s^{-1}

RESEARCH OBJECTIVE

The primary goal of the experiment is to study the behavior and characteristics of plasma positron interaction and annihilation when confined using electromagnetic (EM) fields generated by a Tesla coil inside a sealed vacuum chamber. Under these conditions the first part of the study focuses on using lower range Tesla fields to determine viability of the study design. The second part of the study increases Tesla (T) field strength up to 5 T producing a "pinch(ing)" of the EM Tesla fields. Measured phenomena will include changes in plasma temperature, thermal velocity and annihilations. The results are reported as maximum measured outcomes with graphic display. The third and final part of this research looked at deriving an Annihilation Equation given various Tesla under vacuum conditions which could be used in future research investigations.

METHODS

EQUIPMENT AND MATERIALS

1. <u>Positron Source</u>: A newly available positron emitter radioactive source, using a minimum of 50 millicuries (mCi) of [^{18}F] 2-deoxy-2-fluro-D-glucose (FDG) per study, obtained from Sigma (London) Chemical Co., London S.W.6, U.K., will be used as the positron emitter during decay, in conjunction with any potentially generated positrons from Tesla coil field effect. The ^{18}F (FDG) is introduced into the positron ring centered around the Tesla coil as shown in Figure 3. The t-1/2 (half-life) of ^{18}F is 109.7 minutes.

2. <u>Tesla Coil/Magnetic Confinement</u>: A high-voltage, high-frequency transformer capable of producing strong alternating electromagnetic (EM) fields optimized for 5 T. As Tesla field strength is increased, a "pinch" effect will occur, generating increased plasma temperature (eV), thermal velocity of particles (m/s) and electron-positron annihilations.

3. <u>Vacuum Chamber:</u> The vacuum chamber houses the positron source, plasma generated by Tesla coil, and the Tesla coil itself, along with measurement devices as noted below and complimentary field coils, ensuring minimal interference from air molecules, once the vacuum is applied to the sealed chamber. This chamber needs to maintain a high vacuum (ultra-high vacuum, UHV) to prevent positrons from annihilating (interacting) with electrons in the air. Evacuation of the vacuum chamber to UHV conditions set to 10^{-9} Torr.

4. <u>Magnetic and Electric Field Coils</u>: Additional magnetic and electric field coils to manipulate and stabilize the positron ring and plasma within the chamber.

5. <u>Plasma Formation</u>: Plasma formation will be toroidal, with a rectangular cross-section to ensure that field lines connect back to the magnet, providing a stable confinement area Annihilation-Gamma-based Diagnostic Techniques for Magnetically Confined Electron–Positron Pair Plasma as shown in Figures 3 and 4.

6. <u>Annihilation Detection Apparatus</u>: Systems to detect annihilation events, such as gamma-ray detectors (scintillators, Geiger counters) placed around the chamber to capture the 511 keV photons resulting from positron-electron annihilation.

An array of detectors is positioned around the confinement vacuum chamber to monitor gamma radiation resulting from positron-electron annihilation. These detectors are equipped with pulse-processing hardware designed by Koeman to timestamp detections and measure photon energy, differentiating between two- and three-photon annihilation events

7. <u>Plasma Diagnostic Tools</u>: Langmuir probes will measure plasma (electron) positron annihilation at various Tesla field strength, optical diagnostics including high speed cameras and spectrometers to visualize plasma behavior, or other plasma characterization tools to study the properties of the positron plasma.

Data from the gamma (photon) detectors, plasma diagnostics, and other sensors are collected for analysis.

> <u>Annihilation Rates</u>: The rate at which positrons annihilate with electrons or form positronium (Ps) and subsequently annihilate. This data is crucial for understanding the dynamics of the plasma and the effectiveness of the magnetic confinement.
>
> <u>Spatial Distribution</u>: The spatial distribution of annihilation events within the confinement chamber. This helps in identifying the regions where annihilation is most likely to occur and optimizing the confinement setup.
>
> <u>Annihilation Mechanisms</u>: Differentiating between various annihilation mechanisms such as direct annihilation with free electrons, annihilation with bound electrons, and Ps formation. The contribution of each mechanism is analyzed based on the density and temperature of the plasma.

8. Analysis: The collected data are analyzed to understand the dynamics of positron plasma confinement, the rate of annihilation, and the influence of the Tesla coil's fields on these processes. This includes studying the spatial and temporal distribution of annihilation events and correlating them with the electric and magnetic field configurations.

EXPERIMENTAL PROCEDURE

1. Positron Injection: Positrons are introduced into the chamber from the positron source. They can alternatively be injected in pulses or as a continuous stream, depending on the design of the source.

2. Initialization: The vacuum chamber is evacuated to UHV conditions. The Tesla coil is prepared and calibrated for optimal operation at the desired frequency and voltage.

3. Plasma Formation: The positrons within the chamber form a plasma, a collection of positrons that are not bound to each other but move freely within the influence of electromagnetic fields.

4. Confinement with Tesla Coil: The Tesla coil is engaged and begins generation of high-frequency EM fields with plasma (electron) production. These electrons and EM fields interact with the charged positrons, confining them to a specific region within the chamber. The high voltage from the Tesla coil helps in creating a dynamic containment area due to the rapidly changing fields.

5. Field Stabilization: Additional magnetic and electric fields from Helmholtz equivalent coils surrounding the chamber are adjusted to stabilize the positron plasma. If necessary, creating a magnetic mirror or other magnetic confinement techniques to prevent the plasma from dispersing, helping to focus the electron positron interactions.

6. Monitoring Annihilation: As positrons and electrons interact, they annihilate each other producing gamma photons. The gamma (photon) detectors surrounding the chamber capture these photon events, providing data on the annihilation rate and spatial distribution.

7. Annihilation Rate Data Collection: The experiment runs for five ^{18}F [FDG] half-lives, during which the behavior of the positron electron annihilation is continuously monitored. Data from the gamma-ray detectors, plasma diagnostics, and other sensors were collected for analysis, including the following:

Annihilation Rates: The rate at which positrons annihilate electrons or form positronium (Ps) and subsequently annihilate. This data is crucial for understanding the dynamics of the plasma and the effectiveness of the magnetic confinement.

Spatial Distribution: The spatial distribution of annihilation events within the confinement chamber. This helps in identifying the regions where annihilation is most likely to occur and optimizing the confinement setup.

Annihilation Mechanisms: Differentiating between various annihilation mechanisms such as direct annihilation with free electrons, annihilation with bound electrons, and Ps formation. The contribution of each mechanism is analyzed based on the density and temperature of the plasma.

Density and Temperature Measurement: Langmuir probes will be used to measure the plasma (electron) positron annihilations at various Tesla field strengths.

Optical Diagnostics: High-speed cameras and spectrometers for visualizing plasma behavior.

8. Analysis: The collected data are analyzed to understand the dynamics of positron plasma confinement, the rate of annihilation, and the influence of the Tesla coil's fields on these processes. This includes studying the spatial and temporal distribution of annihilation events and correlating them with the electric and magnetic field configurations.

CHALLENGES AND CONSIDERATIONS OF THIS RESEARCH

Stability: Ensuring the stability of the positron electron (plasma) as positrons tend to rapidly annihilate with electrons.

Field Control: Precise control over the electromagnetic fields to maintain effective confinement without introducing instabilities.

Detection Sensitivity: High sensitivity and accuracy in detecting annihilation photons, as the signals can be weak and potentially masked by unknown or unanticipated background radiation.

By carefully designing and conducting this experiment, we will be able to gain valuable insights into the properties of positron plasma (electron) interactions (annihilations) and the effectiveness of electromagnetic confinement methods, potentially advancing applications in antimatter and plasma physics research.

Chapter 5. Experimental Results

This research is divided into three segments, with the first part of the study looking to determine if plasma (electron) positron annihilation can be adequately controlled in an electromagnetic field of varying strengths generated by a Tesla coil within a controlled vacuum container environment.

The second part of this investigation focused on increasing the Tesla coil strength with subsequent measurement of changes induced within the vacuum chamber as electron positron annihilation was increased through the resulting "pinch(ing)" effect of the EM field.

The third and final part of this research endeavored to derive an annihilation equation based upon quantified measured outcomes over a range of conditions, to be used for future applications including space travel and potential weapons development.

PART 1

Measurements obtained throughout this research looked at a number of variables dependent upon changes in the Tesla field strength. The first part of the study looked at lower Tesla field strengths with qualitative assessment of the plasma condition; i.e., relative electron density. This part of the study focused on determining if plasma positron annihilations could be contained within a Tesla field inside a vacuum chamber environment.

As Tesla field strength was increased, so too did the measured plasma temperature, resulting in higher detectable annihilation counts associated with a greater positron density within the confinement field generated by the Tesla coil. The results are shown in Table 1 below.

Table 1: Testing the feasibility of controlling plasma (electron) positron annihilation using tesla fields.

Magnetic Field (Tesla)	Plasma Temperature (electron volts; eV)	Plasma Condition*	Positron Density (cm^{-3})	Annihilation Rate (counts per second)
0.2	0.5	Ultra-low	1.0×10^{10}	50
0.3	0.8	Very low	1.2×10^{10}	80
0.5	1.0	Low	1.5×10^{10}	100
1.0	2.0	Moderate	3.0×10^{10}	500
2.0	5.0	High	6.0×10^{10}	1000
3.0	10.0	Very high	9.0×10^{10}	1500

* Ultra-low = very few particles; Very low = slightly higher particle density; Moderate = typical laboratory range; Very high = limits of particle confinement.

PART 2

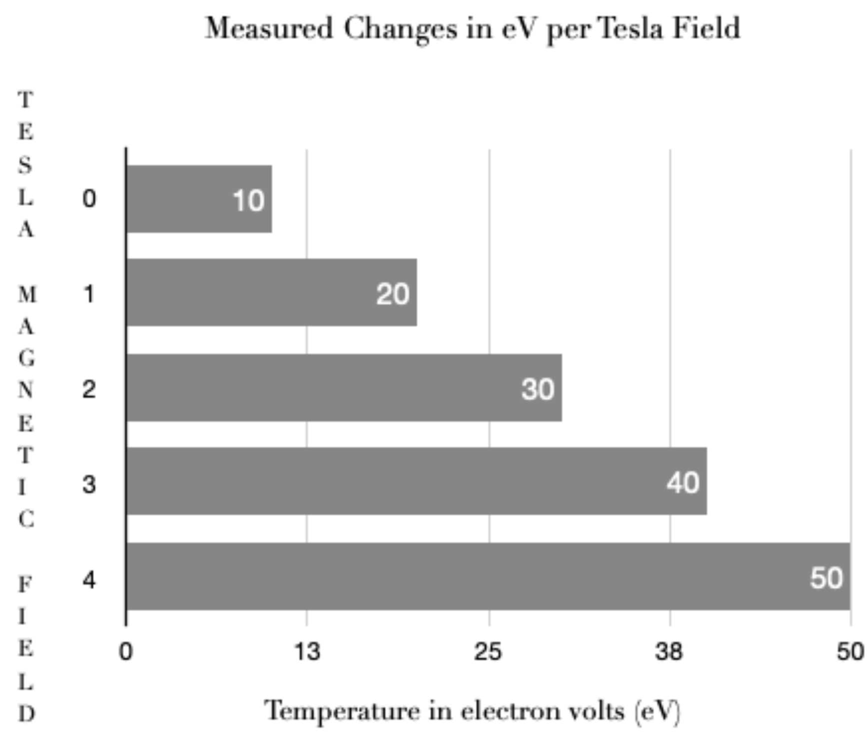
During the second part of this research, under progressively greater Tesla field strengths; measurements of plasma (electron) positron annihilation, time to annihilation, plasma temperature, and thermal velocity of particles, were made to determine if changes in particle interaction could be influenced and controlled by increasing the Tesla coil strength.

As the Tesla strength was increased, the EM "pinch" effect shown in Figure 4 was produced. This resulted in subsequent increases in plasma temperature and thermal particle velocity. This increase was associated with an increase in annihilation rate and inversely related to time to achieve annihilation. The results of the measured outcomes are shown in Table 2.

Table 2: Measured changes in plasma temperature, thermal velocities, annihilation rate and time to achieve annihilation under varying magnetic field strengths.

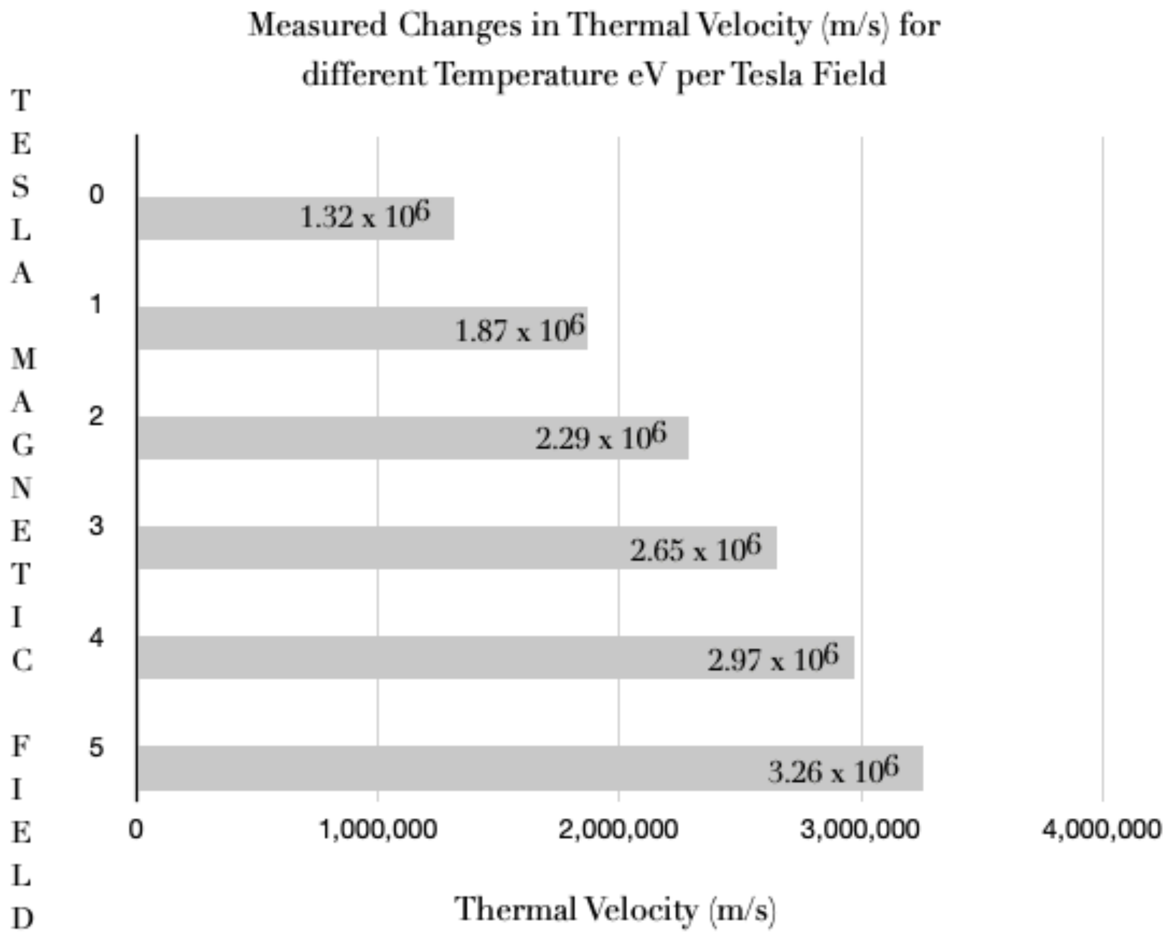
Magnetic Field (Tesla)	Plasma Temperature (electron volts; eV)	Thermal Velocity (meters per second; m/s)	Annihilation Rate (m^{-1} s^{-1})	Time to Achieve Annihilation Rate (seconds)
0	10	1.32×10^{6}	1.47×10^{26}	6.8×10^{-27}
1	20	1.87×10^{6}	2.08×10^{26}	4.8×10^{-27}
2	30	2.29×10^{6}	2.55×10^{26}	3.9×10^{-27}
3	40	2.65×10^{6}	2.95×10^{26}	3.4×10^{-27}
4	50	2.97×10^{6}	3.31×10^{26}	3.0×10^{-27}
5	60	3.26×10^{6}	3.63×10^{26}	2.8×10^{-27}

Both Table 2 and Graph 1, show the relationship between increased Tesla coil strength and subsequently measured increases in plasma temperature.



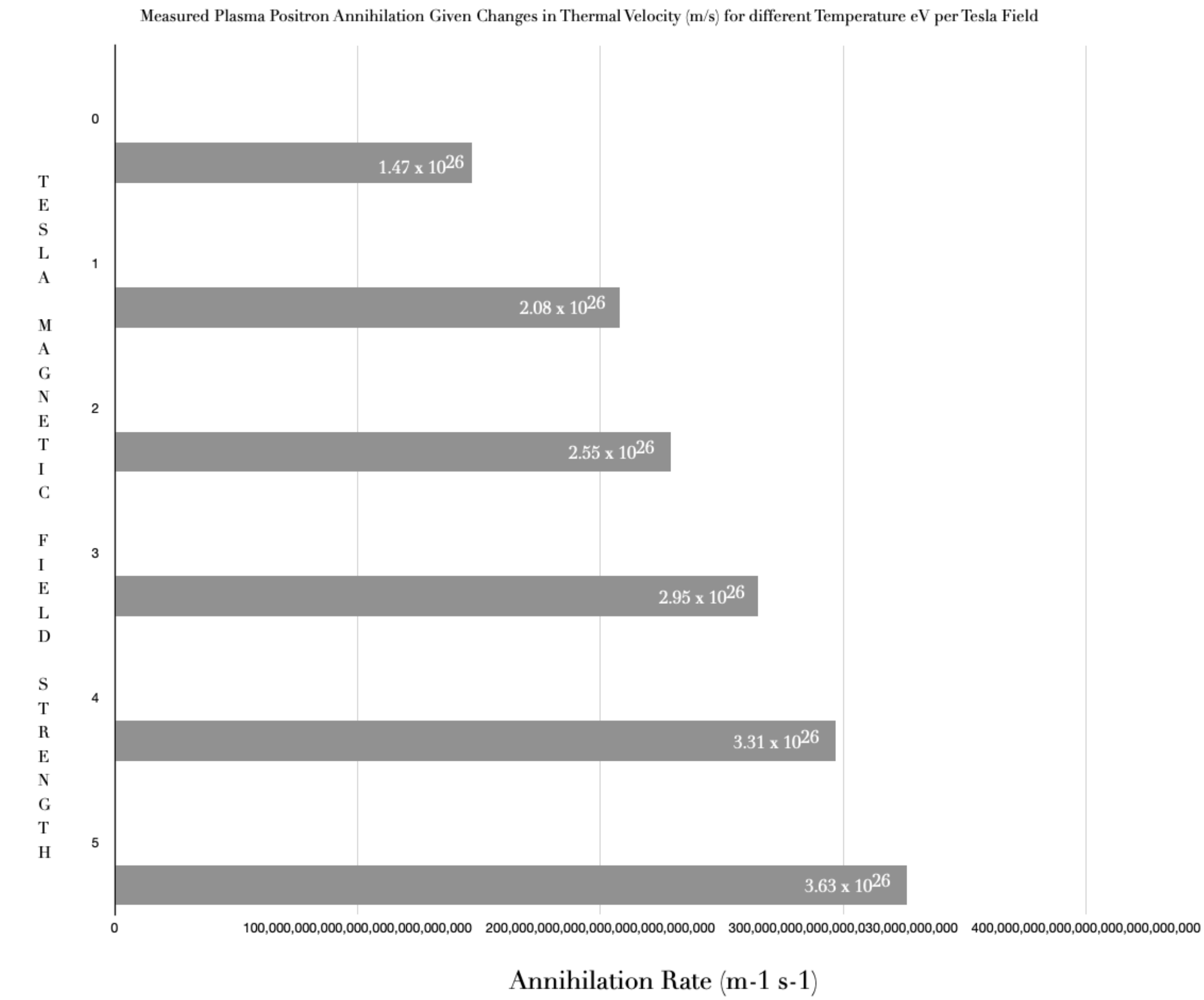
Graph 1. Comparison of increased plasma temperature associated with increased Tesla field strength.

When changes in particle thermal velocity were measured and compared with increased Tesla field strength (Table 2 and Graph 2), there was an initial significant increase in particle thermal velocity noticed following the initial application of Tesla coil field strength. There was a continued increase in thermal velocity with increasing Tesla strength; however, the measured increase was less pronounced with each incremental increase in Tesla field strength.



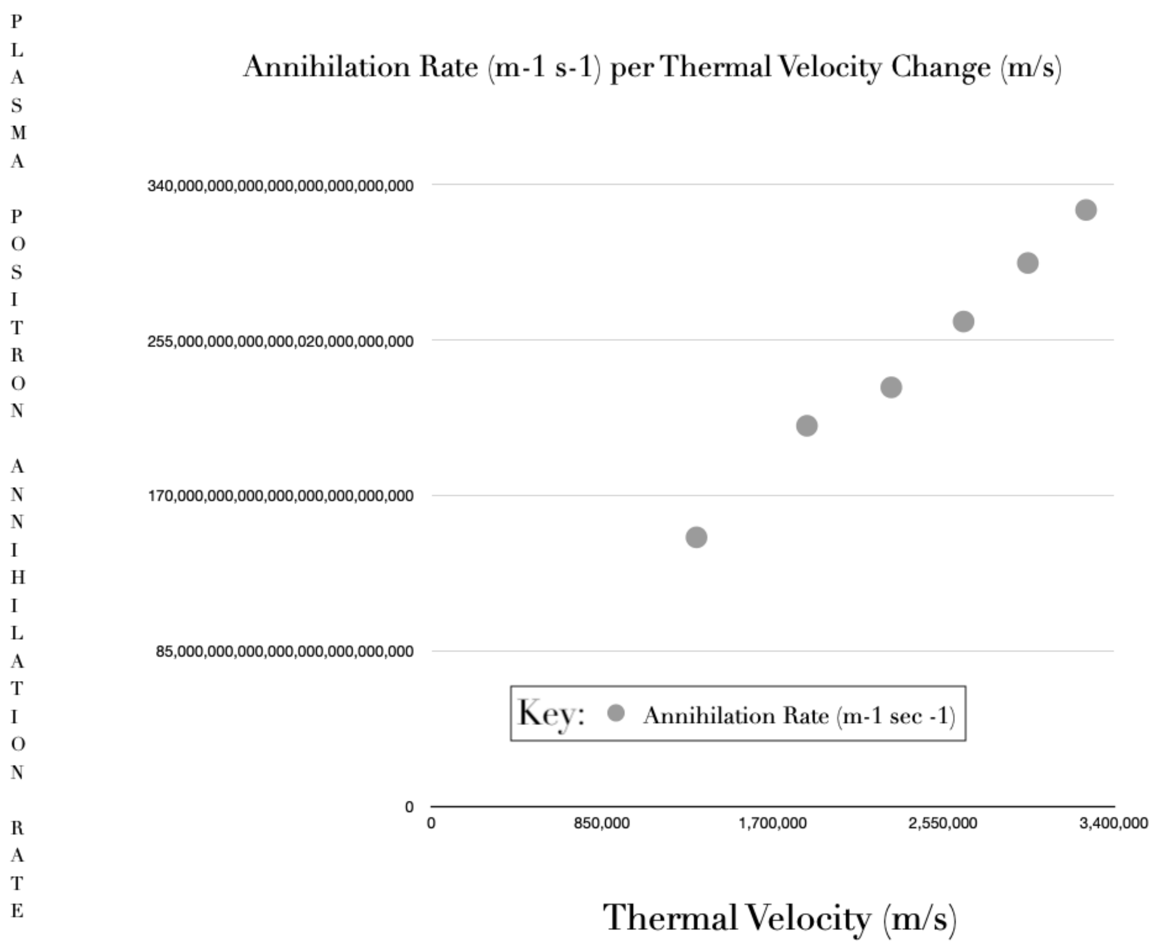
Graph 2. Changes in thermal particle velocity seen in associated increase in Tesla electromagnetic field strength.

When the measured particle velocities are taken into consideration with particle annihilation rate, under increasing magnetic (Tesla) field strength, a progressive, although not completely linear, increase in annihilation rate is seen. This is graphically shown in graph 3.



Graph 3. Comparison of electron positron annihilation with increasing field strength with incorporation of particle velocity.

As shown in the following graphic (Graph 4), there is a steady, almost linear, increase in electron positron particle annihilation seen with increased thermal velocity of the particles, when placed under increased Tesla (Table 2).



Graph 4. The relationship between thermal velocity versus particle annihilation.

PART 3

This data provides the basis for understanding plasma behavior, annihilation dynamics, and confinement efficiency, along with the importance of standardizing the safety protocols ensuring a controlled experimental environment as laid out in the methods section.

In the third and final part of this research, additional measurements to augment the data already obtained and to measure positron confinement.

With the assistance of our IBM mainframe computer, the accumulated data was further analyzed and reduced to a multivariate differential in an effort to facilitate and guide future research under varying condition states. The additional data is shown in Table 3 followed by the derived annihilation equation.

Table 3: Measured positron confinement.

Magnetic Field (T)	Positron Confinement (cm)	Annihilation Rate (10^{10}/second)	Time (seconds) to achieve	Annihilation Localization (cm)	Photon (γ) Radiation Intensity (10^4 photons/cm²/s)
0.1	10	5.0	0.2	10-15	2.0
0.5	5	7.0	0.143	5-10	3.5
1.0	2	10.0	0.1	2-5	5.0
2.0	1	12.0	0.083	1-3	6.0
5.0	0.5	15.0	0.067	< 1	7.5

The resultant calculated electron positron annihilation rate in vacuum cylinder using Tesla field confinement using the cumulative data is:

$$R(t) = \sigma \int_0^{2\pi} \int_0^{\infty} \int_{-\infty}^{\infty} \eta_\rho (r,z,t) \eta_e(r,z,t) v_{rel}(r,z,t) r dr dz d\theta$$

where:

$\eta_p(r,z,t)$ is the positron density in cylindrical coordinates,
$\eta_e(r,z,t)$ is the electron density in cylindrical coordinates, and

R is the radial distance from the axis.

This annihilation rate equation can be further simplified to:

$$R(t) = \sigma\eta_{e0}v_0 \int_0^{2\pi} \int_0^{\infty} \int_{-\infty}^{\infty} \eta_\rho\,(r,z,t) r dr dz d\theta$$

if, and only if,

both the uniform electron density η_e is uniform and constant (i.e., $\eta_e = \eta_{e0}$) and the relative velocity (i.e., v_{rel}) is approximated as a constant (i.e., v_0).

SUMMATION

The results of this research indicate that at lower densities, the electron positron annihilation is primarily limited by transport processes, where positrons diffusing to material surfaces where they annihilate. As the particle density increases, direct annihilation with free electrons and positrons increases, with a reduction in time to annihilation. This process can be facilitated by increasing the Tesla field strength, at least within a vacuum system, resulting in increased particle thermal velocity, plasma temperature and annihilations with reduction in time to annihilation. These changes are associated with a reduction in time to produce annihilation events.

Electrons in a plasma field, along with positron interactions and annihilations can be controlled using changes in EM fields produced by Tesla coil modulation, to influence positron plasma (electron) annihilation processes. This process can be defined by the annihilation equation:

$$R(t) = \sigma \int_0^{2\pi} \int_0^{\infty} \int_{-\infty}^{\infty} \eta_\rho\,(r,z,t)\eta_e(r,z,t)v_{rel}(r,z,t) r dr dz d\theta$$

Chapter 6: Discussion

The introduction of the modern electromagnetic era saw the development of vacuum tube technology, as well as the introduction of the Tesla coil allowing for the transmission of electric current without physical wiring. The importance of this technology was far more important than the competition between Tesla and Edison; it was the use of electromagnetic fields to control ion particle flow.

During the early part of the 20th century, theorized differences in states of matter and different forms of matter, combined with a better understanding of the release of energy with fissioning matter, opened the nuclear age. The limitations in the mass of such a source precluded its use for jet, or other, propulsion systems under gravity conditions; however, it proved applicable for weapons development, although many would argue such an application was more of an abuse than use of this knowledge. Nonetheless, efforts to harness both fission and fusion with breeder reactors have presented potential beneficial applications of this knowledge along with nuclear imaging in research and healthcare, which has seen the introduction of positron technology.

Like fission and fusion, research into positrons first hypothesized by Dirac and later proven by Anderson in the early to mid 1930s, raised new questions about the applicability of these fundamental particles and their potential role in the same fields of endeavor; viz. energy production, weapons development and an increased understanding of subatomic particle physics and medical imaging applications.

Interrogation and integration of the current mathematical models applied to electromagnetic fields, positron and electron particle decay, and the integration of these models under special relativity conditions, indicated that it was possible to both carry out <u>and</u> control, while measuring. positron electron annihilation events in the laboratory setting in a vacuum chamber.

Using the same principles of ion control employed by Tesla, this research investigated whether the use of electromagnetic (EM) fields could be used to both contain and control positron electron (from plasma discharge) annihilation within a vacuum (to enhance annihilations and shorten time to annihilation), thereby channeling that energy for application.

The initial studies carried out in England using zero energy thermonuclear assembly (ZETO) with applied “pinch” effect of EM fields to augment particle velocity and annihilations indicated this possibility.

The initial part of the research demonstrated, that under controlled vacuum state conditions, between 0.2 to 3.0 Tesla field strength, positron electron annihilation could be controlled under varying plasma states and positron density. The results confirmed the expected findings, that increased Tesla resulted in higher plasma (eV) temperature and increased annihilations per second.

Confirmation of these findings were obtained during the second phase of this research carried out over a broader (0 to 5 Tesla) magnetic field range. Measured outcomes and graphic display revealed that the initial increase in thermal velocity was noted during application of the first Tesla, with continued, but less pronounced, thermal velocity noted with further increases in Tesla.

The first two parts of the research demonstrated the ability to control and increase plasma electron annihilations, resulting from increased thermal velocities and plasma temperature. In the final part of this research, additional measurement of annihilation control was demonstrated by measuring positron confinement with increased magnetic field strength. The results showed both an increased confinement of positron and annihilation localization with increased EM field strength. Data was also accumulated showing increased annihilations per second, decreased time to annihilation, and increased photon generation.

From this information it was possible to derive the annihilation rate equation for use with future research design and determination of the energy available for application.

IMPLICATIONS OF THIS RESEARCH FOR SPACE TRAVEL AND WEAPONS DEVELOPMENT

<u>Potential Space Propulsion Systems</u>

The theory and work presented here controlling plasma (electron) positron annihilation using a Tesla coil has important implications for potential space propulsion systems. The ability to manipulate and confine positrons within a plasma offers potential advancements in propulsion systems and energy management in space using either a vacuum system or the rarity of molecules under non-planetary "space" conditions.

1. Propulsion Systems

<u>Electron Positron Propulsion</u>: Efficient control over positron annihilation can lead

to the development of propulsion systems. Such engines promise higher energy densities compared to conventional chemical rockets, potentially reducing travel time to distant planets and stars.

Plasma Thrusters: Utilizing controlled plasma can enhance the performance of plasma thrusters, providing continuous and adjustable thrust, which is crucial for long-duration space missions. Such technology already exists to harness this plasma thrust through the application of θ (theta, direction of current) Bennett pinch application of the Lorentz force; i.e., the compression of the plasma. Stabilization of this application has already been demonstrated using zero energy thermonuclear assembly (ZETA). The term "pinch" is derived from the resulting increased compression of gases, in this instance plasma (electron) positron, with increased magnetic field strength. In this research, the increased magnetic field was generated by Tesla coil of increased Tesla with annihilations measured in this research. The increased annihilation focused energy creates the propulsion system. While not yet published, there is scientific discussion that a group of researchers in the USSR lead by Morozov, et al, have been working on this. Such systems should however only be activated in "space" to avoid potential resulting photon damage from the emissions.

2. Energy Production

Sustainable Energy: Controlled annihilation of positrons and electrons can be harnessed to produce substantial amounts of energy, potentially providing a sustainable and high-density power source for spacecraft. They could, alternatively, also be used for energy generation here on Terra.

Reduced Fuel Requirements: With efficient energy production from positron annihilation, spacecraft can carry less fuel, reducing the overall mass and cost of missions.

Research and Medical Applications

1. Further Research: The information obtained from this research provides new insights into the ability to alter the rate of electron and positron interactions. Future research into this field could increase our understanding of matter antimatter interactions.

2. Medical Applications: The two fundamental fields of medical research with nuclear isotopes include both the treatment of malignancies and imaging of

the body. Future research may yield better isotopes and imaging techniques for both applications.

Weapons Development

The precise control of plasma electron positron annihilation using Tesla coils also presents significant, albeit controversial, implications for weapons development.

1. Directed Energy Weapons

Annihilation-Based Weapons: Harnessing the energy from controlled positron-electron annihilation could lead to the creation of powerful directed energy weapons. These weapons could potentially release immense quantities of energy upon triggering the annihilation process, causing significant destruction.

Focused Energy (Annihilation or Photon): Using electromagnetic fields generated by Tesla coils to direct gamma annihilations could result in highly focused energy, potentially useful for targeting and neutralizing a target with high precision.

2. Antimatter Devices

Compact Destructive Devices: The high energy density of antimatter means that even small amounts can be used to produce massive explosions. Controlled positron storage and annihilation could be used to develop compact, yet highly destructive antimatter bombs. Theoretically, as we know from other research our group has been involved with, such a system could employee the use of ultra-short, MeV-scale laser-plasma positron source for positron annihilation lifetime spectroscopy employing Magnetically Confined Electron–Positron Pairing.

CONCLUDING ETHICAL AND SAFETY CONSIDERATIONS

My plasma positron annihilation theory utilizing Tesla coil confinement, regulation and focus of energy, represents a frontier in both theoretical and applied physics, with the potential to revolutionize space travel by providing more efficient propulsion and energy solutions. Concurrently, the same principles could lead to advanced weapons systems, necessitating careful consideration of the ethical implications and regulatory frameworks to ensure these technologies are used for the benefit of humanity.

Chapter 7: Conclusion

The Fleming theory on plasma (electron) positron annihilation control using a Tesla coil within a vacuum, addresses the interactions of high-voltage, high-frequency electromagnetic fields with electron-positron plasmas. The fundamental idea involves using the unique properties of Tesla coils to influence the behavior of positron electron annihilation, controlling the annihilation processes.

Tesla coils generate strong electromagnetic fields that can ionize gases and create plasma (electron) discharge. These fields are characterized by high voltages and frequencies, which can be harnessed to manipulate charged particles like electrons and positrons. By configuring these coils appropriately, it is possible to confine positrons within a specific region and control their interactions with electrons, thus influencing annihilation rates and patterns.

The practical application of this concept can be seen in the experimental setups where high-intensity lasers create dense electron-positron plasmas. These setups often involve magnetic confinement and diagnostic techniques to measure annihilation rates and spatial distributions of positrons. Both collimators and magnetic fields are useful in focusing and directing electrons and positrons, thereby providing insights into controlling and directing their annihilation.

In essence, combining the high-energy electron plasma environments with the precise electromagnetic control offered by Tesla coils can open new avenues in plasma physics and antimatter research, potentially leading to advances in controlled annihilation processes for various applications, including material science and energy production.

The successful manipulation of positron dynamics using magnetic fields generated by a Tesla coil involves precise control over the positron trajectories and confinement. This is achieved by leveraging the Lorentz force and the oscillating electromagnetic fields of the Tesla coil, which direct the positron motion effectively within the plasma. One proposal for generating a sustainable matter-antimatter source using Tesla coils would be the generation of non-neutral positron traps using a 5 Tesla magnetic coil, feed by a high intensity source of positrons, which as demonstrated in this research, could then be combined with plasma in a levitated dipole trap. The field force of the Tesla coils could both generate the plasma and contain the matter-antimatter annihilation process; after which, the photon energy could either be focused for propulsion, or spontaneously released for potential military purposes.

Like nuclear fission, the potential use and abuse of such energy would most likely revolutionize humanity. In considering the scientific discourses of Einstein as well as the scientists involved in the Manhattan project, and with deep appreciation for the opportunities that have been afforded me with my doctorate training and dissertation, and in recognition of those far more experienced than I am, I propose that my research accordingly be classified, during which time, humanity will hopefully develop the necessary scientific, social and political skill sets necessary to use this research wisely for the betterment of humanity and not its destruction. It is crucial to approach these developments with a strong emphasis on ethical considerations and regulatory frameworks to ensure these findings are used responsibly and for the benefit of mankind.

Chapter 8. References and Sources of Information

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PLASMA POSITRON ANNIHILATION

1. Scientific Journals

Physical Review Letters and Physical Review: These journals published numerous articles on particle physics and plasma physics during that time. A search through their archives for terms like "positron annihilation" and "plasma" would be beneficial.

Journal of Physics B: Atomic, Molecular and Optical Physics: This journal often covered research related to atomic and molecular interactions, including electron-positron annihilation.

2. Books and Monographs

Physics of Fully Ionized Gases: by Lyman Spitzer (1962): This book provides foundational knowledge on plasma physics and may include references to positron interactions.

Positron Annihilation: edited by P.G. Coleman (1969): This compilation of works might include sections specifically focused on positron plasma interactions.

3. Key Researchers and Papers

Paul A.M. Dirac: His work laid the groundwork for understanding antimatter. While his papers date back to the 1930s, they are foundational for understanding positron theory.

Martin Deutsch: Known for his work in positronium and annihilation processes.

Others: Early works by theorists and experimentalists like J.A. Wheeler and others who explored the properties of positron-electron interactions in plasmas.

4. Specific Articles

Additional materials published by researchers such as B. Jean and F. Linder, who studied positron interactions in various media.

Papers by R.S. Quimby and colleagues on the detection and analysis of gamma rays resulting from positron annihilation.

PAUL DIRAC'S WORK ON THE THEORY OF ANTIMATTER AND THE PREDICTION OF THE POSITRON

1. "The Quantum Theory of the Electron" (1928)

Citation: P. A. M. Dirac, Proceedings of the Royal Society A, 117, 610-624 (1928).
Summary: This paper introduced the Dirac equation, a relativistic wave equation for electrons. It was in this paper that Dirac first proposed the concept of negative energy states, leading to the prediction of positrons as holes in the sea of negative energy electrons.

2. "A Theory of Electrons and Protons" (1930)

Citation: P. A. M. Dirac, Proceedings of the Royal Society A, 126, 360-365 (1930).
Summary: Dirac discussed the implications of his equation further, initially suggesting that protons might be the positive counterparts to electrons. However, the mass difference between protons and electrons presented a problem for this interpretation.

3. "The Quantum Theory of the Electron. Part II" (1931)

Citation: P. A. M. Dirac, Proceedings of the Royal Society A, 133, 60-72 (1931).
Summary: This follow-up paper provided a more detailed discussion of the implications of the Dirac equation and corrected earlier interpretations, leading to the eventual understanding that the positive holes in the Dirac Sea were positrons, not protons.

4. "The Theory of Positrons" (1933)

Citation: P. A. M. Dirac, The Physical Review, 82, 403-408 (1933).
Summary: In this paper, Dirac explicitly addressed the existence of positrons, summarizing the theoretical framework and the experimental evidence available at the time, including the discovery of the positron by Carl Anderson.

SELECTED PUBLICATIONS BY IRVING LANGMUIR

1. "Oscillations in Ionized Gases" (1928)

Citation: I. Langmuir and L. Tonks, Proceedings of the National Academy of Sciences, 14, 627-637 (1928).
Summary: This paper described the discovery and theoretical analysis of plasma oscillations, a key phenomenon in plasma physics.

2. "The Interaction of Electron and Positive Ion Space Charges in Cathode Sheaths" (1929)

Citation: I. Langmuir, Physical Review, 33, 954-989 (1929).
Summary: Langmuir discussed the behavior of electron and ion sheaths in cathodes, contributing to the understanding of plasma sheaths and their properties.

3. "The Effect of Space Charge and Initial Velocities on the Potential Distribution and Thermionic Current between Parallel Plane Electrodes" (1923)

Citation: I. Langmuir and K. Blodgett, Physical Review, 22, 347-356 (1923).
Summary: This paper investigated the impact of space charge on potential distribution and current flow in ionized gases.

Langmuir's pioneering work has had a profound and lasting impact on plasma physics, establishing many of the fundamental principles and techniques still in use.

SELECTED PUBLICATIONS BY FRANCIS F. CHEN

1. "Introduction to Plasma Physics and Controlled Fusion" (1974)

Summary: This textbook provides a foundational introduction to plasma physics and controlled fusion. It covers a broad range of topics, from basic plasma properties to detailed discussions on wave phenomena and instabilities.
Impact: Widely used as a teaching resource, it has educated generations of plasma physicists.

2. "Plasma Diagnostic Techniques" (1965) Editors: R.H. Huddlestone and S.L. Leonard, with contributions from F.F. Chen.

Summary: This book includes detailed descriptions of various plasma diagnostic techniques, to which Chen contributed significantly.

POSITRON ANNIHILATION REFERENCES

1. Books

"Physics of Fully Ionized Gases" by Lyman Spitzer. ISBN: 978-0486449820
A foundational text on plasma physics, covering basic principles that are applicable to positron interactions in plasma.

2. Journal Publications

Dirac, P.A.M. (1928). "The Quantum Theory of the Electron" Proceedings of the Royal Society A, 117, 610-624.

This is the foundational paper where Dirac introduced the equation predicting the existence of positrons.

Deutsch, M. (1951). "Evidence for the Formation of Positronium in Gases" Physical Review, 82(4), 455-456.

This describes early experimental evidence of positronium formation in gases.

Ferrell, R.A. (1956). "Theory of Positron Annihilation in Solids" Reviews of Modern Physics, 28(3), 308-332.

Theoretical paper discussing the behavior of positrons in solid materials and their annihilation mechanisms.

3. Review Papers and Conference Proceedings

Brandes, S. & Paulin, R. (1968). "Positronium in Liquids" Physical Review, 175(2), 409-420.

Discusses the formation and annihilation of positronium in various liquid media.

West, R.N. (1973). "Positron Studies of Condensed Matter" Advances in Physics, 22(5), 263-383.

A comprehensive review of positron annihilation in condensed matter, including both theoretical and experimental perspectives.

KEY REFERENCES AND CONTRIBUTIONS ON DEVELOPMENT OF TESLA COILS:

1. Nikola Tesla's Patents and Papers

"System of Electric Lighting" (1891): Tesla's patent (US Patent 454,622) detailing his early work with high-frequency alternating currents and the Tesla coil.

"Experiments with Alternate Currents of High Potential and High Frequency" (1892): A seminal lecture by Tesla explaining his experiments and the principles behind the Tesla coil.

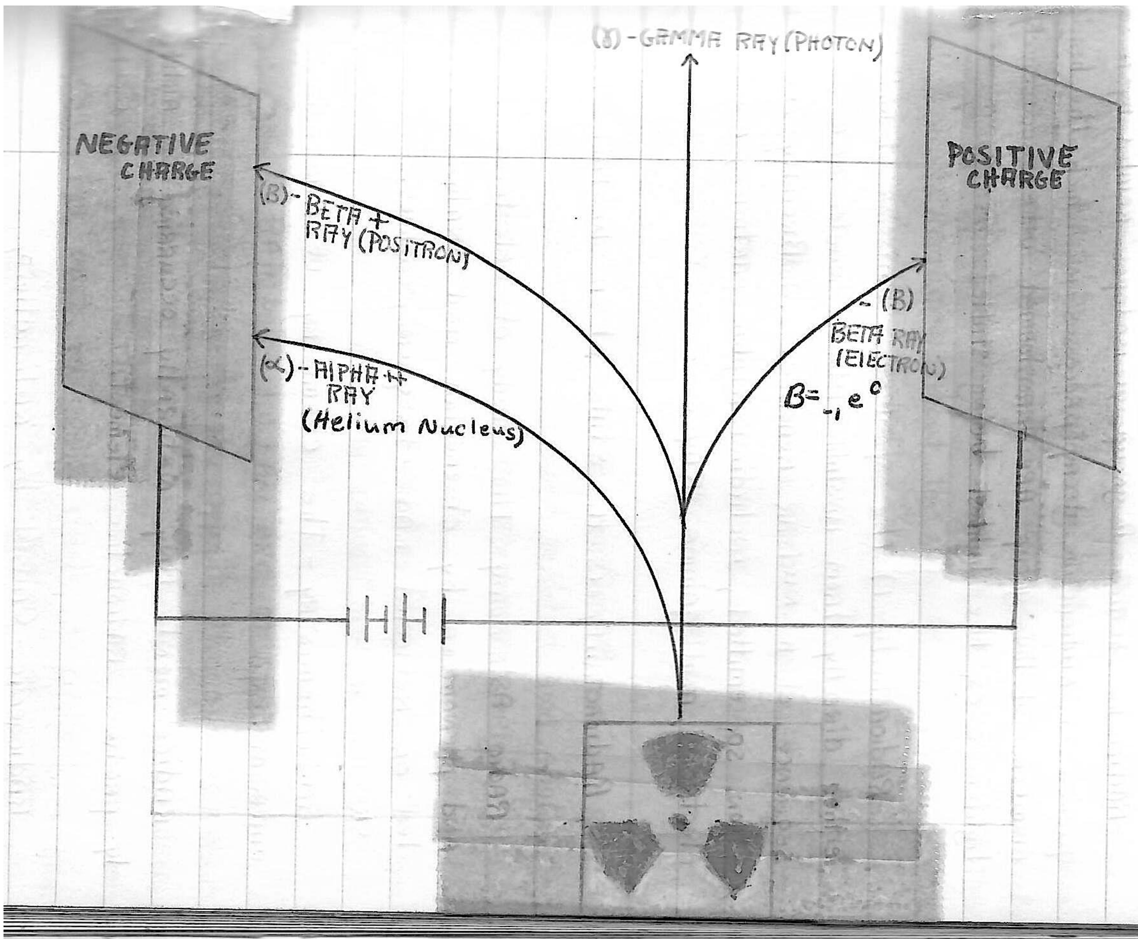
2. Historic Research and Advancements

Fleming, J.A. (1901). "The Principles of Electric Wave Telegraphy": This book describes early applications of high-frequency coils in radio transmission.

Tesla, N. (1904). "The Transmission of Electrical Energy Without Wires": A paper discussing the theoretical and practical aspects of wireless energy transmission using Tesla coils.

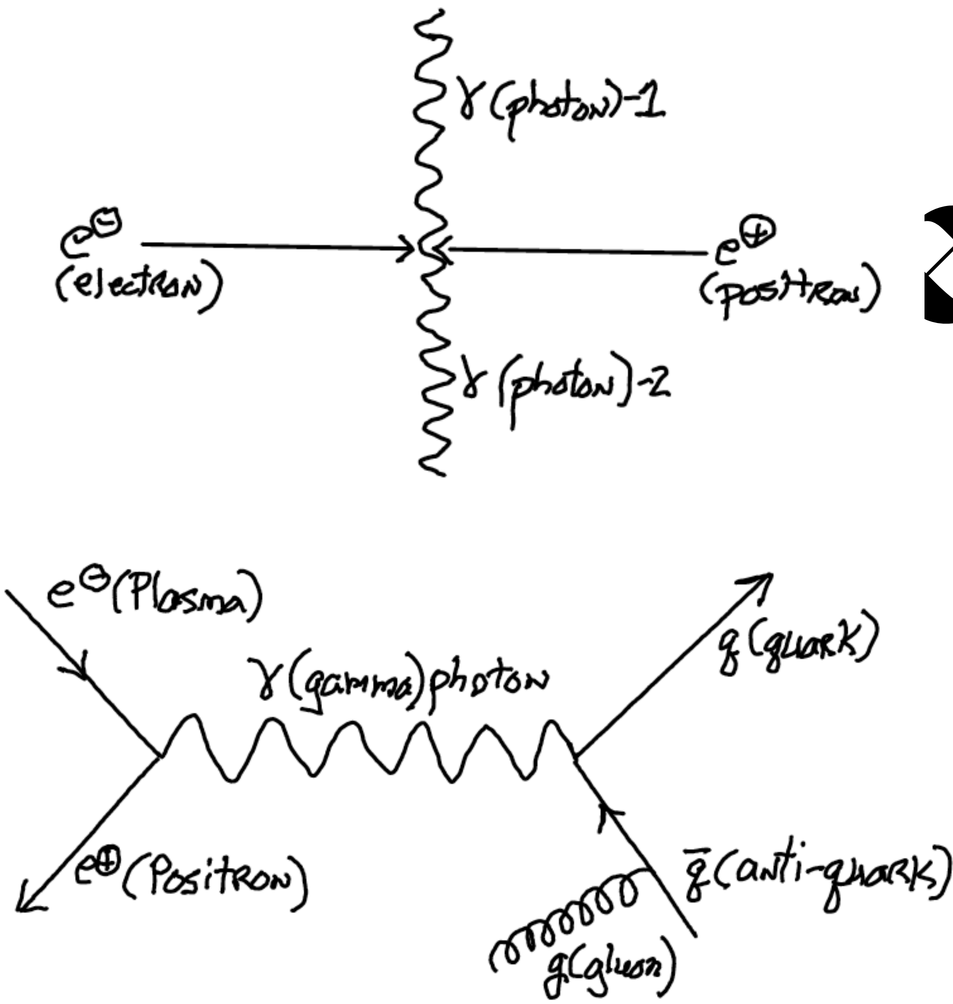
Chapter 9. Figures

Figure 1: Basic Emission of Radioactive Decay.



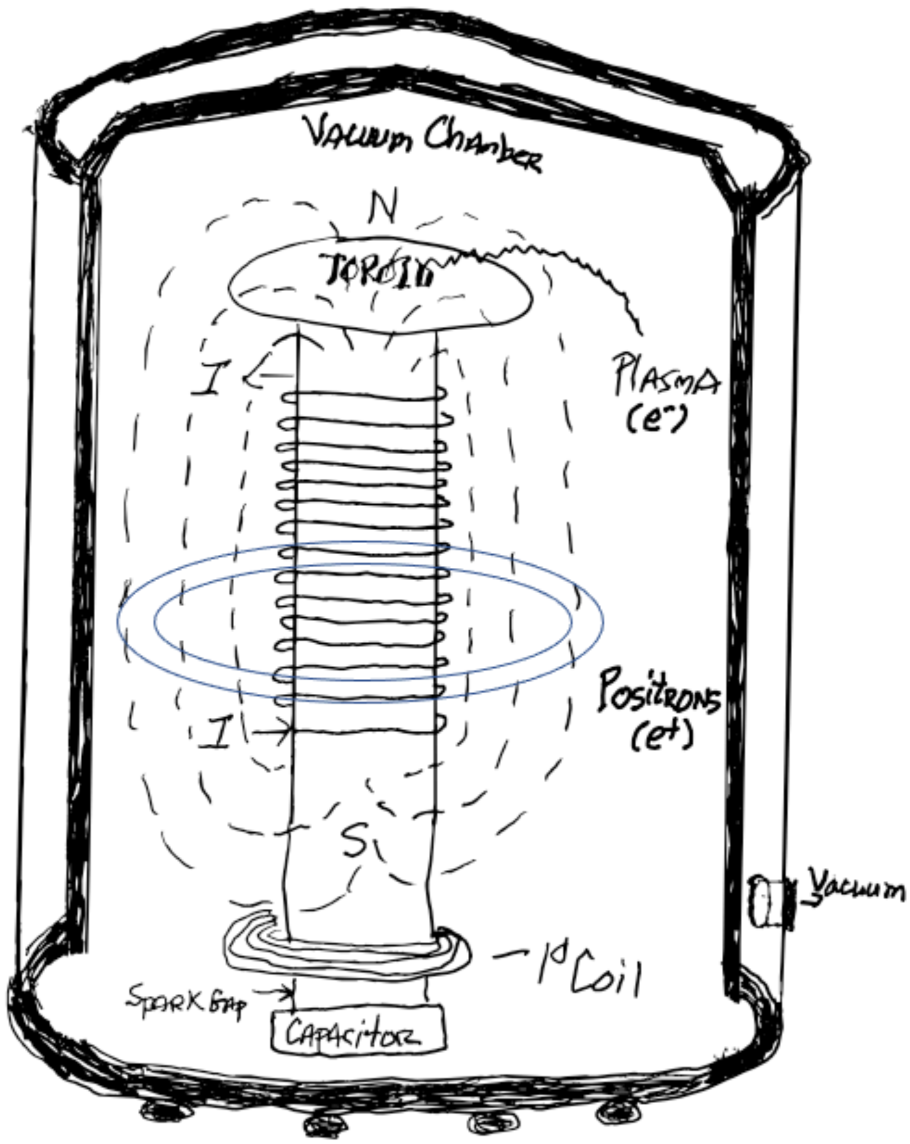
Radioactive decay as symbolized by the universally accepted symbol, yields several particle types which can be differentiated once emitted into an electromagnetic field as shown here. The negatively charged beta particles (electrons; i.e. plasma) is attracted to the positively charged plates; while the positively charged alpha (helium nucleus) and anti-matter positrons, are attracted to the negative plate. Changes in field strength will influence the path of the released particles. As noted, the release of photon (gamma particles) energy is not associated with an electromagnetic shift.

Figure 2: Theoretical models of positron-plasma interaction



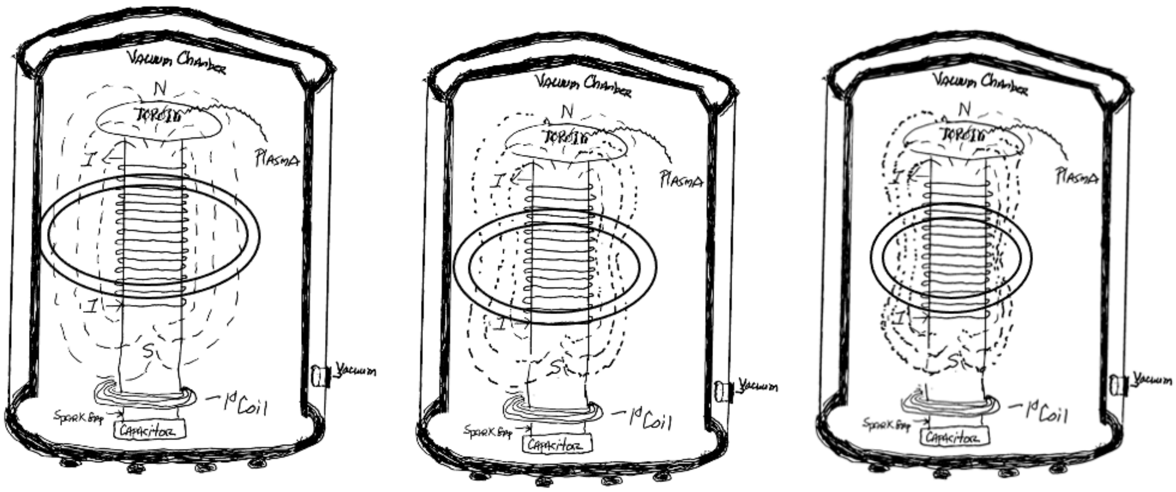
The two figures provide a working understanding of plasma positron annihilation. In the upper figure, a plasma particle (electron) collides with a positron with direct impact resulting in two 511 KeV photons of energy being released. However, when measured using coincidence detection, the measured outcome data reveals the annihilation does not always result in the release of two 511 KeV photons at 180 degrees angulation. The second model represents an alternative hypothesis, where plasma – positron annihilation results in photon energy release with subsequent production of a matter quark (q) and anti-matter quark ($\bar{q}$) pair AND the release of a gluon (g).

Figure 3: Simplified Diagram of experimental setup.



The figure provides a simplified version of the apparatus employed in this research. A Tesla coil is placed within a vacuum chamber, with current supplied (wires not shown for purpose of simplification of diagram) providing varying field strengths. Within the chamber, 18-FDG is placed in the superconductor levitating ring shown in the center of the vacuum chamber. Once the positron source is positioned, the vacuum chamber is sealed the atmosphere within the chamber is evacuated. The current is then applied to initiate the Tesla coil. As the current is increased the Tesla magnetic field increases, producing a "pinching" effect of the magnetic field. Termination of the experiment is obtained using the reverse sequence.

Figure 4: Tesla coil electromagnetic field pattern with increasing "pinch" effect.



Using Tesla coil increased electric field strength results in increased magnetic field strength with a resulting "pinch" effect. This increased pinch effect causes plasma compression along the magnetic field lines, resulting in higher plasma densities and temperatures. Thereby resulting in greater plasma positron annihilation.

Table 1: Matter and Antimatter Subatomic Particles.

Family Name	Particle Name	Particle Symbol*	Anti-Particle Symbol	Mass**	†Particle Electric Charge	Average Lifetime (sec)
	photon	γ	(γ)	0	0	stable
lepton	electron's neutrino	ν_e	$\bar{\nu}_e$	0	0	stable
	muon's neutrino	ν_μ	$\bar{\nu}_\mu$	0	0	stable
	electron	e^-	e^+	1	-1	stable
	muon	μ^-	μ^+	207	-1	2.2×10^{-6}
meson	pion	π^0 π^+	π^0 π^-	264 273	0 +1	0.9×10^{-16} 2.6×10^{-8}
	kaon	K^+ K^0	K^- K^0	966 975	+1 0	1.2×10^{-8} 0.9×10^{-10} or 5.7×10^{-8}
	Nucleon					
	proton	P	$\bar{P}$	1,836	+1	stable
	neutron	N	$\bar{N}$	1,839	0	$1.0 \times 10^{+3}$
baryon	**hyperon**					
	Lambda	Λ	$\bar{\Lambda}$	2,183	0	2.5×10^{-10}
	Sigma	Σ^+ Σ^0 Σ^-	$\bar{\Sigma}^-$ $\bar{\Sigma}^0$ $\bar{\Sigma}^+$	2,328 2,333 2,343	[illegible]	0.8×10^{-10} $< 1.0 \times 10^{-14}$ 1.7×10^{-10}
	Xi	Ξ^0 Ξ^-	$\bar{\Xi}^0$ $\bar{\Xi}^-$	2,572 2,585	[illegible]	3.0×10^{-10} 1.7×10^{-10}
	omega	Ω^-	Ω^+	3,276	[illegible]	1.5×10^{-10}